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THE BISHOP ASH BED AND SOME OLDER COMPOSITIONALLY SIMILAR ASH BEDS IN CALIFORNIA, NEVADA, AND UTAH

By

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ABSTRACT

The Long Valley-Glass Mountain volcanic field of eastern California was the site of numerous eruptions of rhyolitic tephra in late Pliocene to middle Pleistocene time. In the volcanic field, stratigraphic and isotopic age evidence clearly indicate that six pyroclastic eruptions occurred in the age span 2.1 to 1.0 m.y. Three layers of coarse-grained tephra near the Cowan mine and three similar coarse-grained tephra beds at Blind Spring Hill south of Benton Hot Springs, Calif., record episodes of pyroclastic volcanism about 2.1 million years ago. Another layer of coarse-grained tephra near the Cowan mine south of Benton Hot Springs, Calif., records a pyroclastic volcanic event that occurred about 1.0 million years ago. Two layers of volcanic ash interlayered in sediments along the Owens River north of Bishop, Calif. suggest additional pyroclastic volcanic eruptions in the volcanic field at about 1.0 m.y. Ten other pyroclastic eruptions are inferred to have occurred in the volcanic field from about 2.5 to 1.0 million years ago. This speculation is made because numerous ash beds in California, Nevada, and Utah have chemical and mineralogical properties similar to the Bishop Tuff. Because of the protracted history of pyroclastic volcanism in the Long Valley-Glass Mountain region, it seems probable that more pyroclastic eruptive activity will occur in the future. The pyroclastic volcanism is the surface manifestation reflecting the buoyant rise into high levels of the earth's crust of a large granitic batholith that has been evolving beneath the Long Valley-Glass Mountain region in the last three million years.

The pyroclastic materials formed during the many different episodes are united by a common set of chemical and mineralogical properties. These properties are considerably different than the properties of tephra generated at other late Pliocene and Pleistocene volcanic centers in the Western United States. Although the tephra and ash beds are united by overall chemical similarity, small but consistent differences in the amounts of Cs, Rb, U, La, Hf, Ta, Mn, and Fe (determined by instrumental neutron activation analysis) allow their separation. Mineralogically the tephra and ash beds are similar; they all contain quartz, sanidine, oligoclase, biotite, allanite, zircon, apatite, titanomagnetite, and ilmenite. In addition, the upper part of the Bishop Tuff contains orthopyroxene, clinopyroxene, and pyrrhotite.

The catastrophic eruption of the Bishop Tuff 0.74 million years ago was the largest of all the eruptions generated in the Long Valley-Glass Mountain volcanic field. Other eruptions in the Long Valley-Glass Mountain area were small, perhaps about the same volume (about 1.0 km^3) as that ejected during the May 18, 1980 eruption of Mount St. Helens volcano. About 500 km^3 of tephra that now forms ashflows of the Bishop Tuff was expelled from the vent area at Long Valley in a brief time. A large volume of volcanic ash that also was produced during the Bishop eruptive cycle was carried away from the vent by upper stratosphere winds and deposited as a thin blanketlike deposit that must have covered more than a million square kilometers of the Western United States. Remnants of the ash fall are found as far east as central Nebraska, as far south as southern New Mexico, and as far north as southern Idaho. Plinian pumice deposits are 3-4 m thick in the source region. Ash was as least 10 cm thick (compacted thickness) in western Utah, 500 km away from the vent and at least 6 cm thick in eastern Utah, 800 km downwind from the vent. The volume of ash carried away from the vent and distributed widely across the Western United States was enormous, perhaps as much as several hundred cubic kilometers.

Mineralogical and chemical evidence support the idea that a considerable amount of the pyroclastic material that forms Bishop ash beds was generated early in the Bishop Tuff eruptive cycle. The mineralogical evidence was obtained by detailed comparison of Bishop Tuff and Bishop ash beds. The evidence includes 1) the composition of titanomagnetite microphenocrysts, (2) the lack of significant amounts of orthopyroxene and clinopyroxene in Bishop ash beds, and (3) the presence of large amounts of allanite in Bishop ash beds. Trace-element chemical evidence also supports the idea that a considerable amount of the pyroclastic material that forms Bishop ash beds was generated early in the Bishop Tuff eruptive cycle.

Because considerable progress has been made in the techniques and eqiupment used for K-Ar dating since Dalrymple and his coworkers dated the Bishop Tuff in the middle 1960's, 16 new K-Ar age determinations of the Bishop Tuff were made. The weighted mean of sanidine, plagioclase, and biotite ages from the lower nonpyroxene-bearing part of the Bishop is 0.738±0.003 m.y. The weighted mean of sanidine, plagioclase, biotite, and glass ages from the upper pyroxene-bearing part of the Bishop is 0.736±0.005 m.y., nearly identical to the age of the lower unit. The mean age of all new determinations (0.737 m.y.) is not significantly different from the mean age (0.727 m.y.) of the Bishop reported by Mankinen and Dalrymple in 1979. The "best" potassium-argon age for the Bishop Tuff is 0.738±0.003 m.y., which is based on the analytical data for sanidine, which are the most reliable.

INTRODUCTION

The chief purpose of this report is to tabulate previously unpublished mineralogical and chemical data for middle Pleistocene volcanic ash beds that occur at widely scattered localities in the Western United States. These ash beds have properties nearly identical to those of tephra of the Bishop Tuff of eastern California (table 1), and their striking similarity permits their correlation with the Bishop. A second purpose of the report is to provide a map (fig. 1) showing the distribution of the ash beds here correlated with the Bishop Tuff, to present stratigraphic and other information pertinent to the ash localities, and to provide similar information for localities of Bishop Tuff in its source area north of Bishop, Calif. (table 2). A third purpose of the report is to summarize previously published potassium-argon (K-Ar) ages and to tabulate 16 newly determined K-Ar ages for the Bishop Tuff. The final purpose of the report is to present chemical data (table 3) and other information (table 4) for a group of ash beds that are chemically and mineralogically similar to, but older than, the Bishop. These ash beds, which are widely scattered in California, Nevada, and Utah, probably formed during early volcanic stages of the evolutionary magmatic process that culminated in the eruption of the Bishop Tuff.

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BISHOP ASH BED

An enormous volume of rhyolitic tephra was catastrophically erupted about 0.74 million years ago in the Long Valley area of eastern California, resulting in the formation of the middle Pleistocene Bishop Tuff (Gilbert, 1938; Bateman, 1953; 1965; Dalrymple and others, 1965; Sheridan, 1965; 1968; Bailey and others, 1976; Hildreth, 1977; 1979). The eruption that produced the Bishop Tuff lasted only a brief time, perhaps only a few days, and consisted of two clearly discernible stages. During the initial Plinian stage of the eruption cycle, a large volume of tephra was generated that now forms a pervasive, air-fall pumice unit at the base of the Bishop. During an immediately following stage of the eruption cycle, an enormous volume of tephra was produced that now forms sequential, thick ashflows. Volcanic ash also produced during the eruptions was carried downwind and deposited as a thin, blanketlike deposit that must have covered more than a million square kilometers of the Western United States. In favorable sedimentary environments, the Bishop ash fall was covered by younger sedimentary deposits and thus preserved. Widely separated remnants of this formerly blanketlike deposit have been found in Pleistocene deposits and identified as equivalents of the Bishop Tuff (Izett and others, 1970; Borchardt and others, 1972; Merriam and Bischoff, 1975; Sarna-Wojcicki and others 1980). The locations where ash beds have been correlated with the Bishop are shown on figure 1.

In this report the term "tephra" is used to describe pyroclastic material as defined by Thorarinsson (1974, p. xvii), but with a further connotation to the term. Herein the term "tephra" is used to describe pyroclastic material only in volcanic source regions. The term "volcanic ash" is used in this report for the unconsolidated, fine-grained, pyroclastic material far downwind from volcanic vent areas.

PREVIOUS WORK

In the early 1960's, H. A. Powers and R. E. Wilcox of the U.S. Geological Survey suspected that a few volcanic ash beds (locs. 38 and 43, tables 1 and 2) which they had studied in Utah might be downwind correlatives of the Pleistocene Bishop Tuff. In 1970, Izett and others confirmed their suspicion by conclusively matching the chemical and physical properties of these ashes with the basal air-fall pumice unit of the Bishop Tuff. In addition, Izett and others (1970) identified other volcanic ashes in California, Colorado, Nebraska, and Nevada that also have mineralogical and chemical properties nearly identical to air-fall pumice at the base of the Bishop Tuff. Because the Bishop had been dated accurately by the K-Ar method by Dalrymple and others in 1965, the identification of ash beds as Bishop equivalents was particularly important for it provided a dated marker horizon in sediments that enclose the ash beds in areas far removed from the source area. Moreover, correct identification of the ashes as Bishop Tuff correlatives provided important information that allowed refinement of Quaternary faunal and paleomagnetic chronologies on a regional scale.

Borchardt and others (1972) applied the instrumental neutron activation method to the analysis of the same samples studied by Izett and his colleagues and supported their correlation of the volcanic ashes with the Bishop Tuff.

In 1975, Merriam and Bischoff reported chemical data for some ash beds in southern California, and they suggested that these ashes also might be Bishop ash bed equivalents. Izett and Naeser (1976) determined fission-track ages of zircon crystals of Bishop Tuff tephra that are compatible with the K-Ar ages obtained by Dalrymple and his coworkers in 1965. Sarna-Wojcicki and others (1980) correlated ash beds in the Pliocene and Pleistocene Pico Formation near Ventura, Calif., and ash in middle Pleistocene deposits from elsewhere in southern California with the Bishop Tuff.

DISTRIBUTION

More than 40 localities of the Bishop ash are listed in table 2 and plotted on figure 1. Closely spaced localities were given the same location number on figure 1. Several localities of source-area tephra of the Bishop Tuff also are listed in table 2 and shown on figure 1. Occurrences of the Bishop ash are scattered as far east as central Nebraska, as far south as southern New Mexico, and as far north as southern Idaho (fig. 1). The shaded area on figure 1 shows the area where Bishop ash beds have been identified as a result of this study and previous tephrochronologic studies. Almost certainly, additional Bishop ash beds will be found in the future outside the shaded area of figure 1. Dashed lines on figure 1 show the inferred trajectories of plumes of ash that were carried away by upper troposphere winds from the vent area. The nature of such plumes of ash and their positions are highly speculative, and they are only shown on figure 1 to stress the idea that the ash distributional process away from Long Valley during the brief eruption must have been very complex.

IDENTIFICATION AND CORRELATION

Before an ash bed can be identified with a high degree of certainty as a remnant of the Bishop ash fall, its mineralogical, chemical, petrographical, and other physical properties must match closely that of the Bishop tephra of the source area and other previously identified Bishop ash beds. It should be emphasized that a combined approach for the identification and correlation of ash beds must be used. Many different analytical techniques must be used (Wilcox, 1965, p. 813-814; Izett and others, 1972, p. 555) to fully document the range of chemical and physical properties for a particular ash fall such as the Bishop. Moreover, the chemical and physical properties of other ash falls in the same general region and general geologic age must also be explored to insure that no other ash beds match the properties of the ash fall under study. Because it is important to fully explore the properties of other ash beds of similar age before correlations are made, trace-element data for older silicic ash beds in California and adjacent States are presented in table 3 to document their range of variation and the degree of similarity with Bishop ashes.

A question that often arises when dealing with large arrays of tephrochronologic data is how closely must the chemical and physical properties of ash beds agree before their correlation can be considered firm? Of course, an exact numerical match for the amounts of the seven major and several minor rock-forming elements of silicic ash beds is highly unlikely. Even more unlikely is an exact match in chemical composition for a score or more of trace elements commonly searched for in tephrochronological studies. In particular, small differences in chemical analytical data inherently can arise from several sources including (1) spurious analytical variations, (2) systematic analytical variations resulting from measuring by

different analytical techniques, (3) variations resulting from analyzing material of varying purity, (4) natural chemical variations of pyroclastic materials, (5) induced chemical variations arising from sorting by size and density of particles of varying composition during transportation and deposition, and (6) post-depositional changes of glass fragments including hydration and associated chemical changes.

An exact match in measured physical properties of scattered ash beds of the same ash fall is also unlikely. Although the properties of different samples of a tephra fall in its source area may be identical, downwind ash beds related to the tephra fall may have somewhat different properties owing to the possibility that ash carried away from the vent undergoes different transportational, depositional, and post-depositional processes. These processes can induce differences in observed and measured physical properties of ashes found in different geologic and geographic settings. Variations can arise from (1) sorting by size, density, and shape of inhomogeneous pyroclastic materials during transportation, (2) sorting by size, density, and shape during deposition in water or during reworking by wind and water at the depositional site, (3) the introduction of detrital minerals during deposition thereby masking the primary microphenocryst assemblage, (4) varying degrees of hydration resulting in slight variations in the index of refraction of glass shards, and (5) selective dissolution of microphenocrysts by intrastratal fluids resulting in a different mineral assemblage as compared to the erupted material.

Statistical methods, such as the similarity coefficient of Borchardt and others (1972), can aid in the evaluation of a large array of chemical data for a group of ash beds. However, in some instances, only small differences occur in the similarity coefficient for ash beds generated in the same volcanic province but at significantly different times. When similarity coefficients (1.0 is an exact match) calculated from trace-element chemical data for several ash beds are close together (0.90, 0.92, and 0.94), then restraint must be exercised in stating whether or not the ash beds correlate (compare Sarna-Wojcicki and others, 1980, p. 10).

Much more important than statistical analysis, is a full understanding of the effectiveness of various analytical techniques used and an appreciation of the sources of variation other than analytical. In this report, sophisticated statistical analysis of the chemical data alone was not made to estimate the probability of correlation among samples of ash beds and tephra. Instead, the trace-element chemical data for samples of each ash bed were carefully compared and evaluated with the mean values of similar data for samples of the Bishop Tuff (table 1). In addition, petrographic and other physical properties of each ash bed were compared with those of samples of Bishop Tuff tephra to further check the possibility of correlation.

The ash beds, whose locations are shown on figure 1 and listed in table 2, are herein correlated with the Bishop Tuff on the basis of their similar mineralogy, chemical composition of glass shards (table 1), chemical composition of sanidine, titanomagnetite (table 5), and ilmenite microphenocrysts, and shape and refractive index of glass shards. Some of these chemical and petrographic data are not given in this report because they have been presented in earlier studies of Bishop ash beds (Izett and others, 1970) and Bishop Tuff (Hildreth, 1977; 1979). It should be stressed that the probability of correlation of each ash bed with the Bishop Tuff made in this paper is high, based on the agreement between many chemical and physical properties. However, correlations can never be absolutely certain because ash

beds erupted from the same volcanic center but at slightly different times can have nearly identical properties. For example, the Glass Mountain-G and Glass Mountain-D ash beds (Izett, 1981, p. 10217) almost surely were erupted from vents in the same region as the Bishop Tuff, but during earlier volcanic episodes. These ash beds have chemical (tables 1 and 3) and physical properties nearly identical to the Bishop, and their distinction from the Bishop, lacking stratigraphic or geochronologic evidence, is not always possible. Therefore, a slight chance exists that some ash beds here correlated with the Bishop actually are Glass Mountain ash beds. However, the eruptions that produced the Glass Mountain-G and Glass Mountain-D ash beds were probably small and did not result in the formation of thick beds of ash at localities far removed from the source area.

MINERLALOGY OF BISHOP TUFF AND BISHOP ASH

One of the assumptions made in tephrochronology is that all geographically separated remnants of an ash fall should contain the same assemblage of primary microphenocrysts as their suspected source tephra. Furthermore, the chemical composition of each type of microphenocryst in downwind ash beds should mimic very closely the chemical composition of the same kind of microphenocryst in the source area tephra. However, the assemblage of primary microphenocrysts in a volcanic ash bed often can be masked by the addition of detrital minerals to the primary assemblage during deposition. Another complicating factor is that under some geologic conditions, primary microphenocrysts (as well as detrital species) in ashes can be selectively dissolved by intrastratal solutions. Not only can the original microphenocryst assemblage be modified by dissolution or contamination, but the abundance of a microphenocryst species in a downwind ash may differ considerably from the abundance in source-area tephra owing to the affect of eolian differentiation (Murray and Renard, 1884, p. 486; Larsson, 1937) during transportation, but also owing to the affect of fluvial and eolian processes during deposition.

Mineralogic descriptions of the Bishop Tuff and Bishop ash beds have been reported by Gilbert (1938), Sheridan (1965), and Izett and others (1970). More recently, Hildreth (1977; 1979) made a detailed study of the vertical and lateral chemical changes in the composition of primary minerals in samples of the Bishop Tuff using the electron microprobe. These studies of the Bishop demonstrated that its primary mineral assemblage consists of broken and euhedral crystals of high temperature beta quartz, sanidine, oligoclase, biotite, orthopyroxene, clinopyroxene, pale-pink zircon, allanite, titanomagnetite, ilmenite, and pyrrhotite. Apatite has been found only as inclusions in zircon, allanite, and biotite. Zircon, titanomagnetite, and ilmenite are invariably small, nearly complete euhedral crystals; quartz, sanidine, oligoclase, and allanite are generally broken crystals or cleavage fragments.

Many ash beds herein correlated with the Bishop Tuff are so pervasively contaminated with detrital heavy minerals that the full complement of primary microphenocrysts that characterizes the Bishop could not always be found in samples of the ash beds. However, a few glass-coated crystals of quartz, sanidine, oligoclase, biotite, allanite, zircon, titanomagnetite, and ilmenite were found in heavy mineral concentrates of all ash samples herein correlated with the Bishop, including the most pervasively contaminated ones. Glass-coated primary crystals could only be identified by microscopic study of heavy mineral concentrates of the ashes mounted in immersion oil having an index of

refraction near to that of the host ash (n=1.496). Recognition of those crystals that had glass coatings among the multitude of detrital heavy minerals that had no glass coatings was facilitated by using a petrographic microscope equipped so that the focal masking technique (Wilcox, 1962) could be used.

The Bishop Tuff seemingly can be divided into two stratigraphic parts, on the basis of mineralogical differences observed by Hildreth (1977; 1979) and confirmed by our study of the Bishop. Whether the mineralogical difference used in this report to divide the Bishop Tuff into two parts coincides with a mappable lithologic break has not as yet been determined. A lower part of the Bishop contains quartz, sanidine, oligoclase, biotite, zircon, allanite, titanomagnetite, ilmenite, and apatite. An upper part contains the above listed minerals, but in addition, contains orthopyroxene, clinopyroxene, and pyrrhotite. The presence of pyroxene in the youngest, uppermost ash flows of the Bishop is according to Hildreth (1977, p. 89), "...a useful stratigraphic indicator". He (1977, p. 1-2) suggested that the appearance of orthopyroxene and clinopyroxene in the youngest ash flows of the Bishop reflects the tapping of a mineralogically, chemically, and thermally zoned magma chamber. According to his model, the upper cooler part of the Bishop magma chamber was erupted first and now forms the lower, older part of the Bishop Tuff that lacks orthopyroxene and clinopyroxene. A deeper, hotter part of the magma chamber was erupted last and now forms the youngest, stratigraphically highest, orthopyroxene- and clinopyroxene-bearing ash flows of the Bishop.

An exception to Hildreth's mineralogical observation concerning the distribution of orthopyroxene and clinopyroxene in the Bishop was found by the writer. Rare pumice lapilli in a surge deposit (fig. 2) that overlies the basal air-fall pumice unit of the Bishop at the California Insulating Aggregate quarry about 10 km north of Bishop, Calif. (table 2, locality 1) contain both glass-mantled orthopyroxene and clinopyroxene identical to the same mineral species in the uppermost ash flows of the Bishop. Perhaps a deep part of the Bishop magma chamber that contained orthopyroxene and clinopyroxene was tapped early in the Bishop eruptive activity. An alternative explanation is that a chemically and mineralogically different (pyroxene-bearing), but closely related magma, was tapped early as well as late during the eruptive cycle that formed the Bishop. Presumably this magma occupied a deeper but adjacent position to the Bishop magma.

Another significant mineralogical difference can be used to distinguish the lower part from the upper part of the Bishop. The lower part contains titanomagnetite whose chemical composition is consistently different than titanomagnetite of the upper part. The author made a compilation (table 5) of the chemical data for this mineral, as determined by Hildreth (1977, p. 31-37), using the electron microprobe. The data are arranged in approximate ascending stratigraphic order for the various ash flow lobes of the Bishop named by Hildreth. Temperatures of equilibration for coexisting titanomagnetite and ilmenite from glassy samples of the Bishop were calculated by Hildreth (1977, table 4) using a method based on the curves of Buddington and Lindsley (1964). On this basis, tephra of the lower part of the Bishop seemingly formed from magma that was distinctly cooler (720°C-773°C) than was tephra of the upper part of the Bishop (763°C-790°C). A more detailed analysis of the chemical data for titanomagnetite was made by Hildreth (1977). He reported a systematic upward change (1977, fig. 4) in the chemical composition of titanomagnetite and associated ilmenite, and accordingly, an attendant systematic upward change in calculated equilibration temperature.

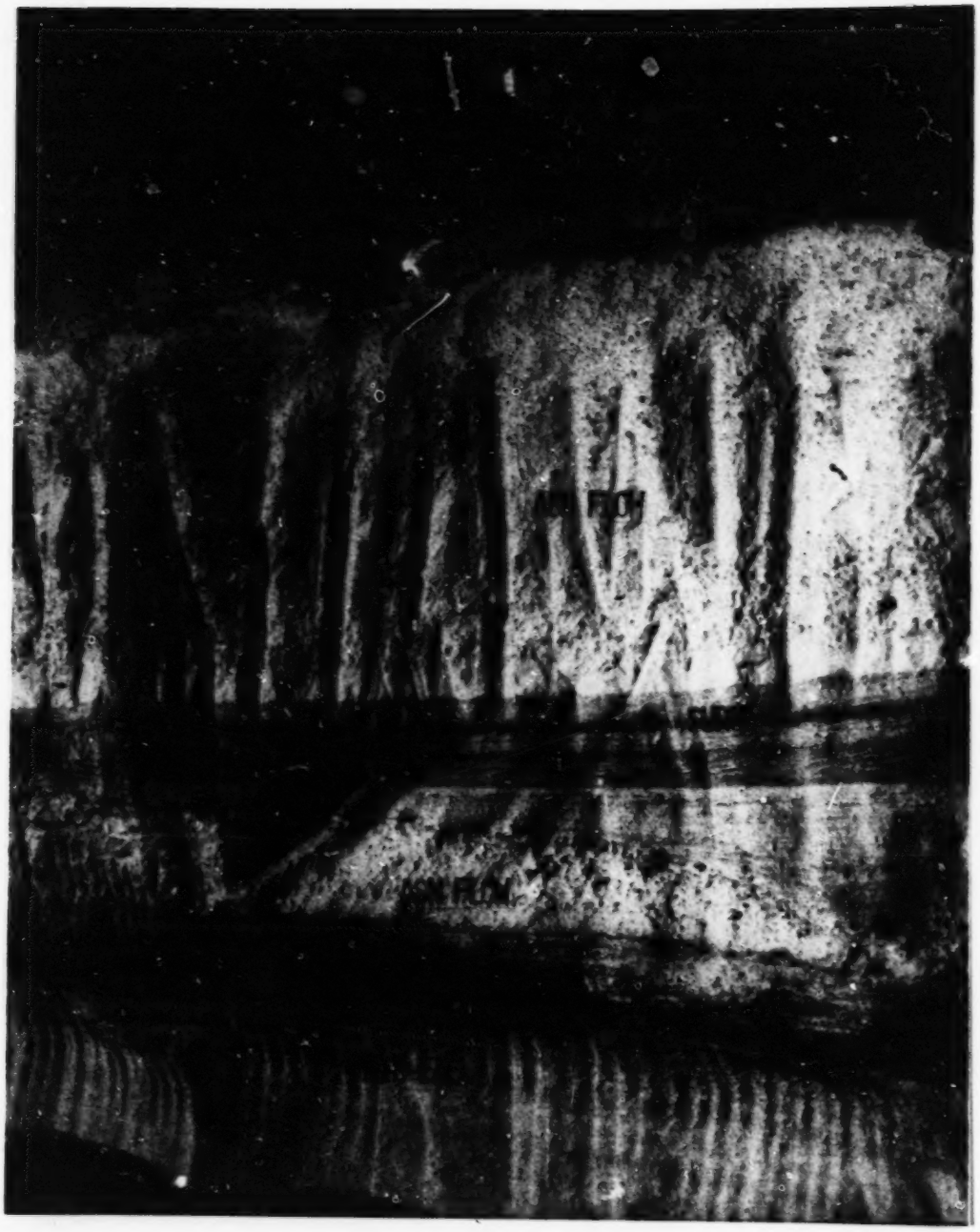

Figure 2.--Photograph of the lower part of the Bishop Tuff at the Insulating Agrregate quarry about 10 km north of Bishop, Calif. A basal air-fall pumice unit is overlain by a thin, lenticular ashflow which in turn is overlain by a thin, pumice-rich surge deposit followed by a thick ashflow. Pyroxene microphenocrysts were found in a few pumice lumps from the surge deposit. Air-fall unit is about 4.0 m thick (base not exposed); surge deposit is about 1.0 m thick.

There are several other mineralogical differences between the lower and upper parts of the Bishop, but they are not as evident as the difference in the pyroxene content. There may be a tendency for biotite in pumice lapilli from the lower unit to be pale-yellowish-brown, whereas there may be a tendency for biotite from pumice lapilli of the upper unit to be dark-brownish-black. Moreover, sanidine in pumice lapilli of the air-fall unit apparently has a slightly lower potassium content than does sanidine from some ash-flow units (Hildreth, 1977, p. 51, fig. 6; this report, table 7).

Another mineralogical difference between the lower and upper parts of the Bishop was reported by Hildreth (1977, p. 16 and 106). He concluded that allanite was restricted to the upper part of the Bishop that yielded Fe-Ti-oxide mineral temperatures below 763°C. In contrast to the conclusion reached by Hildreth, I found small amounts of allanite in some pumice blocks from the uppermost ash flows of the Bishop at localities B-137 and B-138 of Hildreth (1977, p. 299). He (1977, p. 46) reported Fe-Ti-oxide temperatures of 770°C and 778°C for samples he collected at these localities (B-137 and B-138). The allanite microphenocrysts were found by making heavy liquid separations of large amounts (10-20 kg) of material from the meticulously cleaned pumice blocks that were used for K-Ar age studies described elsewhere in this paper. Perhaps allanite occurs in all units of the Bishop, but the amount of allanite in the stratigraphically highest ashflows is much less than in the lowest units of the Bishop.

Some of the mineralogical information described in this report bears on the question of whether the pyroclastic material that comprises Bishop ash beds of figure 1 was generated (1) during the initial Plinian stage of the Bishop eruption, (2) in conjunction with the emplacement of the successive ash flows of the Bishop, or (3) throughout the eruptive episode that produced the Bishop Tuff. Considerable trace-element data are also presented later in the report that bear on this question and, equally important, support the correlation of these beds with the Bishop Tuff.

Several mineralogical lines of evidence concerning the Bishop Tuff may be used to attack the problem of whether the pyroclastic material that now forms Bishop ash beds was produced during the early Plinian stage, during the following ashflow-producing stage, or throughout the eruptive cycle. One line of evidence pertains to the composition of titanomagnetite microphenocryts in Bishop ash beds. The composition of primary titanomagnetite in samples of the least contaminated Bishop ash beds is nearly identical to the composition of titanomagnetite microphenocrysts in source-area tephra of the lower part of the Bishop (tables 5 and 6). Scores of individual glass-encrusted titanomagnetite microphenocrysts from the least contaminated Bishop ash beds were analyzed using the electron microprobe. All primary crystals in the ash beds were found to have compositions similar to the titanomagnetite from the lower part of the Bishop; not a single crystal was found to have a composition similar to the titanomagnetite of the stratigraphically highest ash flows of the Bishop. Titanomagnetite crystals from the upper, pyroxene-bearing part of the Bishop contain significantly more aluminum and magnesium and less manganese than do crystals of this mineral from the nonpyroxene-bearing part of the Bishop (table 5).

A second line of mineralogical evidence concerns the relative abundance of allanite in Bishop ash beds. Glass-coated or glass-mantled fragments of allanite readily can be found in all samples of ash herein correlated with the Bishop, including those pervasively contaminated with detrital minerals. Furthermore, the amount of allanite in the ash, relative to the amount of

other accessory minerals is large. This observation, paired with the fact that allanite is much more abundant in the lower part of the Bishop compared to the upper part, suggests to me that most of the material that forms Bishop ash beds was erupted early in the eruptive cycle.

A third mineralogical line of evidence concerns the absence of orthopyroxene and clinopyroxene in some samples and its paucity in other samples of Bishop ash. Most samples of ash herein correlated with the Bishop contain extremely rare primary crystals of glass-coated orthopyroxene. Curiously, glass-coated clinopyroxene, which is equally as common as orthopyroxene in the stratigraphically highest ash flows, was seen in only a few ash samples. The presence of relatively large amounts of orthopyroxene and clinopyroxene in pumice of the upper part of the Bishop in the source area, and the paucity of these minerals in samples of Bishop ash, sugggest to me that the material that forms Bishop ash beds was formed early in the eruptive cycle. The combined mineralogical observations described above concerning the composition of titanomagnetite and the occurrence of allanite, orthopyroxene, and clinopyroxene suggest to me that a considerable amount of the material that forms Bishop ash beds probably originated during early stages of the eruptive cycle, mainly during the highly energetic Plinian phase.

CHEMICAL COMPOSITION OF BISHOP TUFF AND BISHOP ASH BEDS

In the past four decades, samples of volcanic ash beds and tephra have been extensively analyzed to establish their chemical "fingerprint" so they may be characterized and correlated. Tephrochronologic studies involving the chemical analysis of ash beds have been done by Swineford and Frye (1946), Powers and Malde (1961), Powers and others (1958), Jack and Carmichael (1968), Izett (1968), Theisen and others (1968), Smith and Westgate (1969), Izett and others (1970), Borchardt and Harward (1971), Borchardt and others (1972), Izett and others (1972), Sarna-Wojcicki (1976), Nash and Smith (1977), Sarna-Wojcicki and others (1979), Scheidegger and others (1980), and Sarna-Wojcicki and others (1980).

The instrumental neutron activation method has proven to be particularly useful for the trace-element fingerprinting and correlation of silicic volcanic ash beds (Theisen and others, 1968; Borchardt, 1970). Results of chemical analyses by this method for a large number of Bishop ash beds and pumice samples by this method are tabulated in table 1. Analyses were made of glass fragments separated from crushed pumice lumps of the Bishop Tuff and of glass shards separated from samples of ash suspected to be remnants of the Bishop ash fall. The instrumental neutron activation analyses were made by three different analysts using slightly different methods at different times. Analyses were made by G. A. Borchardt of the California Division of Mines and Geology in the early 1970's, by H. R. Bowman of the University of California (reported in Sarna-Wojcicki and others, 1980) in the late 1970's, and by H. T. Millard, D. M. McKown and R. J. Knight of the U.S. Geological Survey from 1975 to 1981. Some of the minor variations in the amounts of a few trace elements reported in table 1 might be attributed to intralaboratory bias. If there is intralaboratory bias, it is small and does not seriously influence the identification and correlation of the ash beds of this report.

Hildreth (1977; 1979) reported instrumental neutron activation analyses of the glass phases of samples of the Bishop Tuff. Based on sequences of samples collected in stratigraphic succession, he concluded that the Bishop Tuff is compositionally zoned. For example, samples of pumice from the stratigraphically lowest unit (basal air-fall) contain significantly less lanthanum, cerium, and europium and more uranium than do samples from the uppermost pyroxene-bearing unit of the Bishop (Hildreth, 1977, figures 22 and 23; this report, table 1).

As can be seen on table 1, the composition of glass shards of ash beds here assigned to the Bishop closely matches the composition of the glass fragments from pumice lapilli of the basal air-fall unit of the Bishop Tuff in its source area. In particular analyses of ash from localities 8, 9 (Salton-1 and Salton-5), 12, 14, 22, 25, 26, 29, 30, 31-33, 36, and 38-46 show remarkable similarity to analyses of the air-fall unit of the Bishop Tuff (table 1). The composition of Bishop ash beds are also similar to the composition of most of the samples collected from the stratigraphically lowest ash flows of the Bishop Tuff (table 1). However, one sample (loc. 1, sample no. 79G15, table 1) of pumice from the basal ash flow of the Bishop Tuff contains slightly more lanthanum, cerium, and europium and less uranium than do other samples of the lower units of the Bishop.

Ash from several localities, including 9 (Salton-2 and Salton-2A), 10, 19, 21-24, 27, 34, 35, and 40 (table 1) herein assigned to the Bishop ash, contain amounts of lanthanum (about 23-30 ppm), cerium (50-57 ppm), europium (0.08-0.13 ppm), and uranium (5.5-6.5 ppm) slightly larger than samples of the basal air-fall unit of the Bishop (about 16-19 ppm lanthanum, 35-45 ppm cerium, 0.02-0.05 ppm europium, and 6.5-8.0 ppm uranium). Samples of ash from several of these localities (27, 34, 35 and 40) were reanalyzed (table 1) to determine if the larger amounts of lanthanum, cerium, and europium and smaller amounts of uranium might be attributed to variations arising from using imperfectly cleaned samples or to variations from using samples of slightly different grain size. However, in most instances reanalyzed samples of the ashes consistently mirror the analytical results of prior analytical runs and contain larger amounts of lanthanum, cerium, and europium and smaller amounts of uranium. Several conditions might explain why some ash beds here included with the Bishop contain more lanthanum, cerium, and europium and less uranium than the other samples.

One possibility is that samples of ash that contain the smallest amounts of lanthanum, cerium, and europium and the largest amounts of uranium were erupted during the earliest phase of the eruption cycle associated with the emplacement of the basal air-fall unit and the lowest ash flows of the Bishop Tuff (Hildreth 1977, p. 200-203; this report, table 1). In contrast, the ash samples that contain the largest amounts of lanthanum, cerium, and europium and the smallest amounts of uranium may contain a large component of material that was generated during the late stages of the eruption cycle associated with the emplacement of the stratigraphically highest ash-flow units of the Bishop Tuff. Inspection of table 1 shows that the samples of Bishop ash that contain the smallest amounts of lanthanum, cerium, and europium and largest amounts of uranium (typical of samples of the basal air-fall unit of the Bishop Tuff) were collected from near the base of Bishop ash beds in zones that seemingly formed during the early phase of the ash fall [table 1, localities 31 (sample 79G4), 36 (sample 80G15), 38, 39, 43, 45, and 46].

Samples of Bishop ash that contain the largest amounts of lanthanum, cerium, and europium and smallest amounts of uranium (characteristic of ash flows of the upper part of the Bishop Tuff) were collected from the upper parts of ash beds that probably formed during late stages of the ash fall. The stratigraphically highest parts of the ash beds have bed forms that indicate ash was washed or blown into the depositional site following the deposition of the primary ash fall.

Another possiblity, which is not probable in my opinion, is that samples of ash beds that contain the relatively largest amounts of lanthanum, cerium, and europium are not Bishop ash beds. The fact that they are petrographically, mineralogically, and stratigraphically similar to the Bishop as well as having a chemical composition, in most respects, similar to the Bishop suggests to me that they are Bishop ash beds, but of a slightly different type.

As can be seen on table 1, the composition of the glass shards of ash beds herein correlated with the Bishop closely match the composition of the glass phase of tephra from the basal air-fall unit of the Bishop Tuff in its source area. On the other hand, the composition of glass shards of these ash beds markedly contrasts with the glass phase of tephra from the uppermost ash flows that contain orthopyroxene and clinopyroxene (table 1, locality 7). Samples of the upper part of the Bishop contain significantly less iron, manganese, scandium, tantalum, lutetium, uranium, rubidium, and cesium. However, they contain more of the light, rare-earth elements lanthanum and cerium than do samples of the lower unit of the Bishop. Hildreth (1977, p. 175, 213) suggested that the concentration of iron doubled during the eruption of the Bishop. Thus, amounts of iron should be greater in samples from the upper part of the Bishop as compared to samples from the lower part. This is indeed true for many of the whole rock analyses listed by Hildreth (p. 176-184), especially for samples from the Adobe Valley and Mono lobes of the Bishop. In contrast, some analyses of glass separated from pumice of the upper unit of the Bishop from Adobe Valley reported by Hildreth (1977, p. 200-203) and those listed in table 1 (this report) indicate that the glass shards from the upper part contain less iron than glass shards from the lower part of the Bishop.

The combined mineralogical and chemical evidence support the idea that a considerable amount of the pyroclastic material that forms Bishop ash beds was generated early in the Bishop Tuff eruptive cycle. The mineralogical evidence for Bishop ash beds described in a previous part of this report, including the composition of titanomagnetite microphenocrysts, the lack of significant amounts of orthopyroxene and clinopyroxene, and the large amounts of allanite are particularly important. Chemical evidence also supports the idea that a considerable amount of the pyroclastic material that forms Bishop ash beds was generated early in the Bishop Tuff eruptive cycle. Hildreth (1977) concluded that the Bishop Tuff is a chemically zoned ashflow sheet. He showed that the earliest units of the Bishop Tuff contain the smallest amounts of lanthanum and cerium and the largest amounts of uranium. Progressively younger parts of the Bishop contain more lanthanum and cerium and less uranium. The fact that the chemical composition of many Bishop ash beds matches closely the composition of the air-fall tephra unit at the base of the Bishop, supports the contention that a considerable amount of the material that forms Bishop ash beds was generated early in the eruptive cycle, perhaps mainly during the

energetic Plinian phase of the eruption. Some samples of Bishop ash contain slightly more lanthanum and cerium and less uranium than samples of tephra from the basal air-fall unit of the Bishop Tuff (table 1). This fact suggests to me that some material that forms Bishop ash beds was generated during the eruption of the lowest ashflows of the Bishop, which contain slightly more lanthanum and cerium and less uranium compared to air-fall tephra. The chemical composition of glass shards of the youngest, pyroxene-bearing ashflows are strikingly different than the bulk composition of glass shards of Bishop ash beds. This evidence seemingly rules out the possibility that the youngest eruptions, which produced pyroxene-bearing pumice, contributed much material to the formation of Bishop ash beds.

VOLUME OF BISHOP ASH

Calculation of a minimum value for the volume of Bishop ash that was erupted and carried far downwind is seemingly a simple task assuming that (1) the areal distribution of the original ash fall is known and (2) the relationship between ash thickness and distance from source can be established throughout the fallout area. The areal distribution of the Bishop ash is fairly well established (fig. 1), but not enough thickness data are available to arrive at a relibale volume estimate. Using the distribution of the Bishop ash bed as it was known in the early 1970's (Izett and others, 1970) and by assuming a logarithmic thinning (compare Williams and Goles, 1968; Walker, 1980, p. 76-77) away from the vent area, Bailey and others (1976, p. 730) estimated the volume of the Bishop ash fall to be about 300 km^3. Conversion of this volume to the volume of dense rock equivalent requires only an assumption for the bulk density of the ash.

To obtain a more accurate estimate of the volume of Bishop ash demands a better understanding of the areal distribution of the original ash fall and a detailed knowledge of the nature of the logarithmic thinning away from the vent area. The thickness of the Plinian pumice fall in the source area can be determined at many localities; it ranges from 3-4 m in thickness. However, it is extremely difficult to find localities where the thickness of the primary air-fall component of Bishop ash beds can be recognized and measured. Ideally, ash beds consist of two depositional units: a lower unit of primary air-fall ash and an upper unit of secondary water- or wind-redeposited ash (fig. 3). Careful study of many localities of Bishop ash suggests that at only two localities can the thickness of primary air-fall ash be determined with reasonable confidence. One locality is on the west side of the Mineral Mountains in southwestern Utah (locality 36, fig. 1) about 500 km downwind from the vent area. At this locality, the Bishop ash bed is locally 3.0 m thick. However, I judge that the air-fall component of the 3.0-m-thick ash bed at this locality is only about 10 cm thick. Of course, this thickness (10 cm) is a compacted-ash thickness; the original thickness of air-fall ash, shortly after deposition, must have been considerably thicker (16 cm? thick). At a second locality in eastern Utah (locality 38, fig. 1), about 800 km downwind from the vent area, the Bishop ash is about 1.0 m thick. I surmize that the air-fall component of the ash bed at this locality is only about 6 cm thick (fig. 3). Of course, this thickness (6 cm) also represents compacted ash, and the original air-fall ash may have been as thick as 10 cm.

In conclusion, the number of localities where the primary air-fall ash thickness can be measured is so small that the rate of thinning away from the vent can not be accurately determined. This factor imposes a serious obstacle

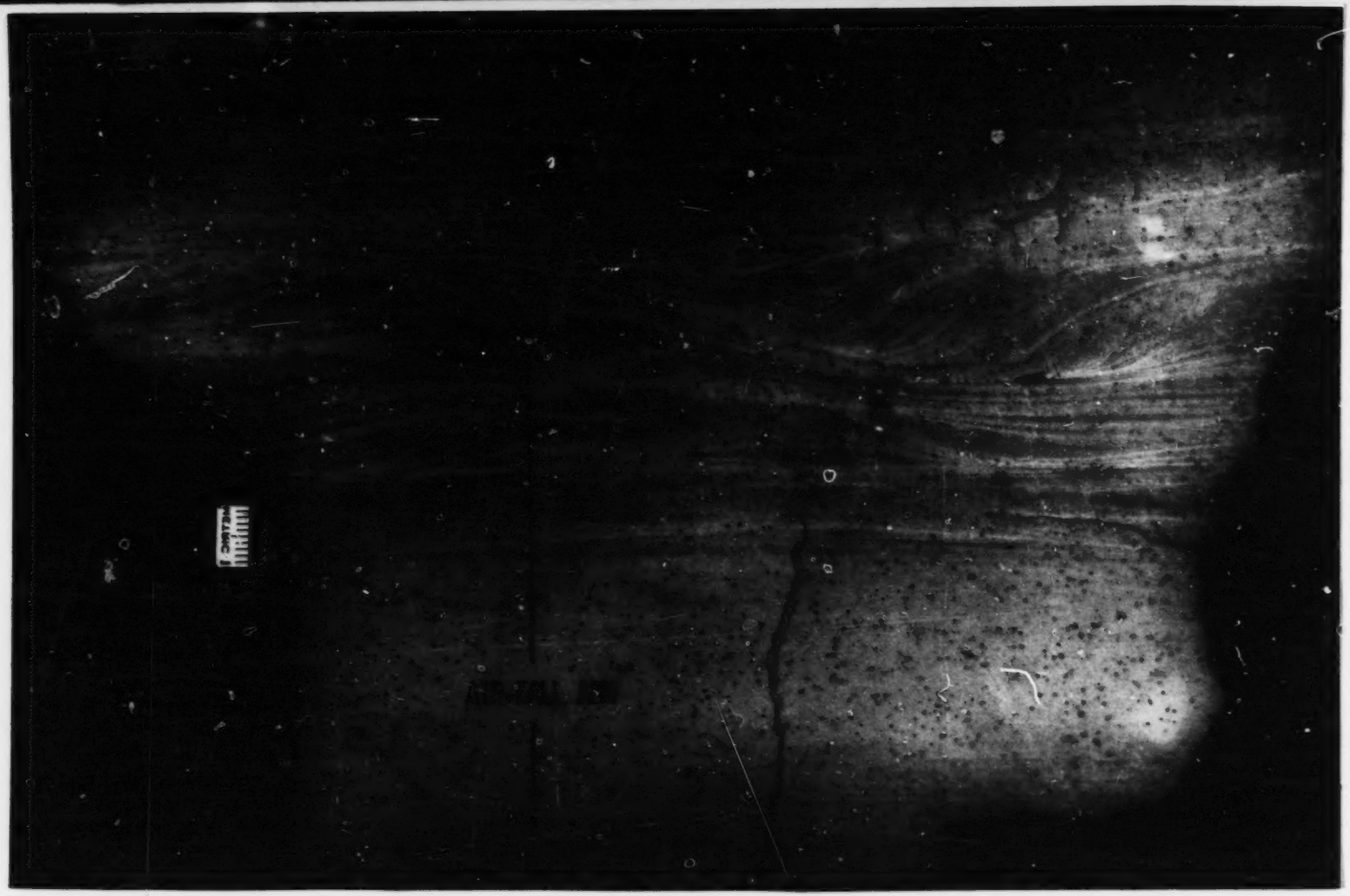

Figure 3.--Photograph of a sawed slab of ash collected from the lowermost part of a 1-m-thick Bishop ash bed at Onion Creek, Utah (locality 38, fig. 1). Base of ash bed at bottom picture. Lowest 6 cm of ash bed may be primary air-fall ash; upper 8 cm is crossbedded eolian? redeposited ash. Scale in left part of photograph is 1 cm.

to those interested in calculating ash volumes produced from prehistoric pyroclastic eruptions such as the Bishop. Although there is insufficient reliable thickness data to arrive at a meaningful volume for the Bishop ash fall, nevertheless, the volume must have been enormous based on the wide distribution of Bishop ash localites (fig. 1). The volume may have been several hundred cubic kilometers as Bailey and others (1976, p. 730) suggested.

POTASSIUM-ARGON AGE OF BISHOP TUFF

The Bishop Tuff has been the object of repeated attempts to determine accurately its age by the K-Ar method (Evernden and others, 1957; Dalrymple and others, 1965; Hildreth, 1977, p. 327). Recalculation of K-Ar ages for the Bishop using the analytical data of Dalrymple and others (1965) and decay constants and isotope abundances being used in 1976 resulted in a weighted mean age of 0.708±0.015 m.y. at the 95 percent confidence level (Bailey and others 1976, p. 731). The K-Ar age of the Bishop Tuff was recalculated by Mankinen and Dalrymple (1979, p. 619). They used decay contsants and isotope abundances advocated by Steiger and Jager (1977) and analytical data of Dalrymple and others (1965) to arrive at an age of 0.727 m.y. for the Bishop.

Because considerable progress has been made in the techniques and equipment used for K-Ar dating since Dalrymple and his coworkers dated the Bishop in the middle 1960's, several new K-Ar age determinations for the Bishop were made. Samples were collected from the stratigraphically lowest and uppermost parts of the Bishop Tuff to determine if the lowest part (nonpyroxene-bearing pumice unit) might yield consistently older ages than the stratigraphically youngest part (orthopyroxene- and clinopyroxene-bearing ash-flows). Newly determined K-Ar ages are reported here (table 7), as well as ages determined by Dalrymple and others (1965) and Hildreth (1977). All ages listed in table 7 were calculated or recalculated using the decay constants and isotope abundances recommended by Steiger and Jager (1977).

The weighted mean age calculated from a series of determinations made on sanidine, plagioclase, and biotite from the lower nonpyroxene-bearing part of the Bishop is 0.738±0.003 m.y. at the 1 sigma level. The weighted mean age for only sanidine (0.738±0.003 m.y.) from the lower unit is identical to the weighted mean calculated for all minerals. The weighted mean age calculated from the sanidine ages determined in this study (0.731±0.004 m.y.) is nearly identical to the other weighted mean ages for the lower unit.

The weighted mean age calculated from a series of determinations made on sanidine, plagioclase, biotite, and glass from the upper pyroxene-bearing part of the Bishop is 0.736±0.005 m.y. at the 1 sigma level. This mean age is nearly identical to the weighted mean age calculated for the lower unit. The weighted mean age calculated for only sanidine ages (0.722±0.007 m.y.) from the upper unit is slightly younger than the weighted mean age of all minerals. A slightly younger weighted mean age for sanidine is a consequence of three of the six sanidine ages clustering around 0.70 m.y. and the other three clustering around 0.74 m.y. The weighted mean age calculated for the four sanidine ages determined in this study is 0.743±0.005, slightly older than the weighted mean age for all sanidine ages. Perhaps the younger sanidine ages resulted from the less than complete expulsion of argon from the samples.

The only age (1.36±0.13 m.y.) that seems anomalous is one determined on plagioclase from the lower unit of the Bishop (DKA3958, table 7). The most likely explanation for the anomalous age is that the plagioclase sample prepared for the age determination was so inhomogeneous that the sample splits used for potassium and argon analysis differed in potassium content. A large amount of quartz could not be completely removed from the plagioclase during the mineral separation process, and the amount of the potassium-bearing phase (plagioclase) relative to the nonpotassium-bearing phase in the sample was small.

The ages determined on biotite and glass (table 7) have large analytical uncertainties owing to the samll amount of radiogenic ^{40}Ar obtained, relative to the total ^{40}Ar extracted (table 9). Naeser and others (1981, p. 30-31) recently emphasized the unreliabilty of K-Ar ages having a low ratio of radiogenic ^{40}Ar to total ^{40}Ar.

A plot of $^{40}Ar/^{36}Ar$ against $^{40}K/^{36}Ar$ using the analytical data (table 8) acquired from sanidine, plagioclase, biotite, and glass from the lowermost and uppermost parts of the Bishop is shown on figure 4. The intersection of the isochron along the ordinate is about 298, which suggests that there is no analytically detectable amount of excess ^{40}Ar in the sanidine, plagioclase, biotite, or glass. The age of the Bishop Tuff, including samples from the stratigraphically lowest and highest units, based on the isochron, is 0.74 m.y.

PREPARATION OF SAMPLES FOR POTASSIM-ARGON DATING

In the field, pumice lapilli and blocks collected for K-Ar age determinations were handpicked from the walls of pumice quarries. In the laboratory, groups of pumice lapilli were ultrasonically scrubbed in dilute hydrofluoric acid (about 1 percent), washed in water, and dried. Only those pumice lapilli that would float in water were selected for mineral separation; heavier accidental lithic fragments were excluded using this technique. The outer rinds of large pumice blocks from ash-flow units of the Bishop were ground away or trimmed off with a rock saw to reduce the possiblity of contamination by xenocrystic material in the outer vesicles and tubes of the pumice. Following crushing, washing, drying, and sizing of the pumice fragments, mineral separations were made using standard heavy liquid techniques. The purity of the concentrates resulting from the heavy liquid separations was improved by removing glass coatings on the minerals with dilute hydrofluoric acid (10 percent) and recycling the mineral concentrates through heavy liquids. The purity of the mineral concentrates was further improved by use of a magnetic separator. After the samples were sized for the final time, they were split, using a Jones-type microsplitter, into fractions for argon and potassium analysis. Argon was extracted from melted mineral concentrates by G. A. Izett, J. D. Obradovich, and H. H. Mehnert; argon isotopic ratios were measured by H. H. Mehnert and J. D. Obradovich using a mass spectrometer at the U.S. Geological Survey's K-Ar laboratory at Denver, Colo. Potassium was determined by flame photometry using a lithium internal standard and by isotope dilution techniques.

The following conclusions are made from study of the K-Ar ages of the Bishop:

1. The mean age of newly determined K-Ar ages for the Bishop reported herein (0.737 m.y.) is not significantly different from the mean age (0.727 m.y.) of the Bishop reported by Mankinen and Dalrymple (1979, p. 619).

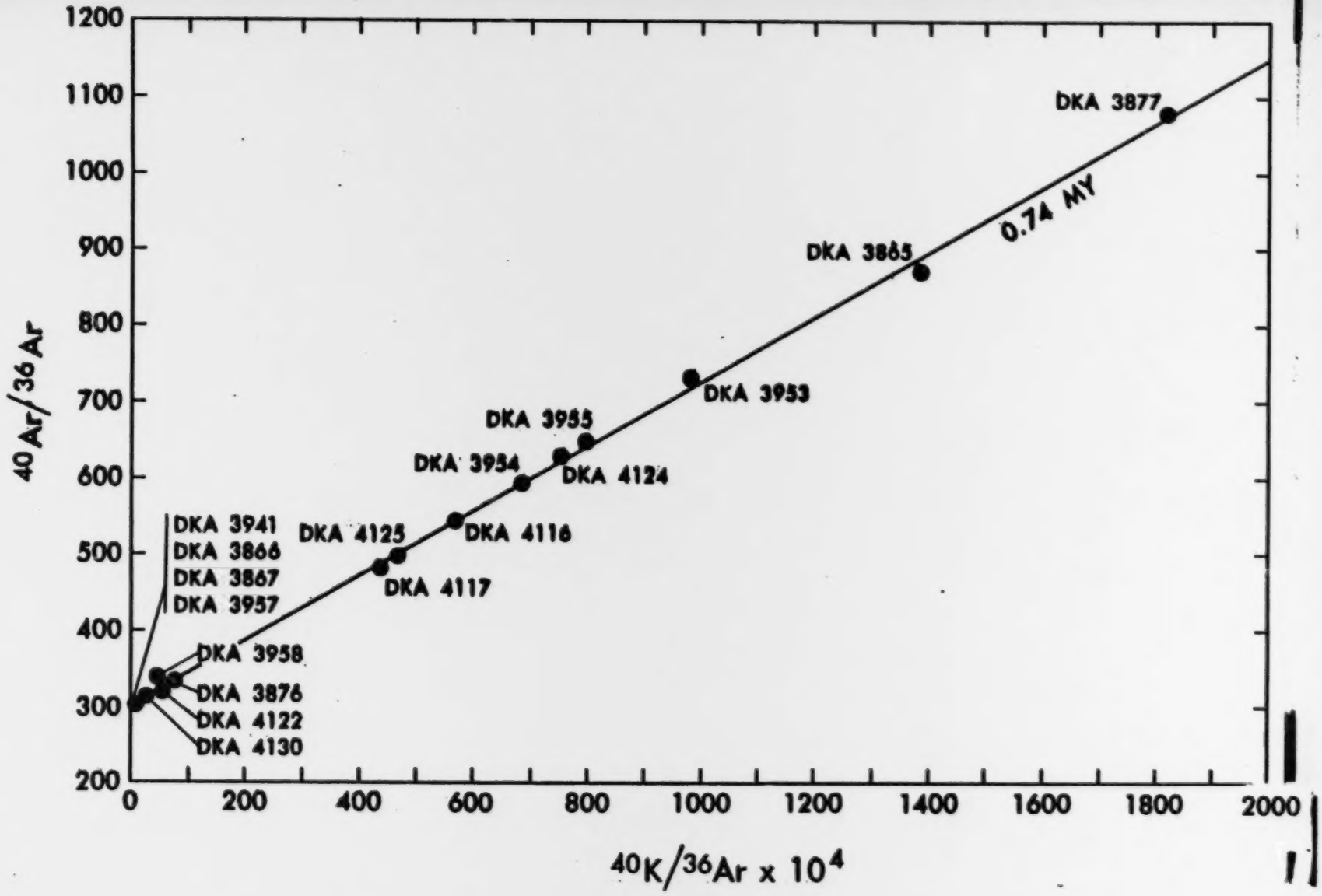

Figure 4. Plot of argon and potassium isotopes ($^{40}Ar/^{36}Ar$ vs $^{40}K/^{36}Ar$) measured in samples of sanidine, plagioclase, biotite, and glass separated from samples of the Bishop Tuff. Sample numbers (DKA3877) are those of table 7 and 8.

2. The average K-Ar age of 0.738±0.003 m.y. as determined in this study is nearly identical to the average zircon fission-track age (0.74±0.05 m.y.) reported by Izett and Naeser (1976) for the Bishop Tuff.
3. There is no significant age difference between the lowest nonpyroxene-bearing and the uppermost pyroxene-bearing parts of the Bishop.
4. Minerals and glass that comprise the Bishop Tuff do not contain analytically significant amounts of excess radiogenic argon.
5. The "best" K-Ar age for the Bishop Tuff is 0.738±0.003 m.y. at the 1 sigma level. This age was calculated using only the analytical data for sanidine which are considered by me to be the most reliable.

OLDER ASH BEDS AND TEPHRA UNITS SIMILAR TO THE BISHOP TUFF

For many years it has been known that the Long Valley area north of Bishop Calif., is the location of vents from which tephra was erupted that now forms the Bishop Tuff (Smith and Bailey, 1968, p. 629; Bailey and others, 1976; Hildreth, 1977; 1979). Moreover, it is becoming increasingly clear that the episode of silicic, pyroclastic volcanism that produced the Bishop Tuff was not the only one that occurred in late Pliocene to middle Pleistocene time in the area north of Bishop, Calif., although it certainly was the largest. Evidence is accumulating (Sarna-Wojcicki and others, 1980; Izett, 1981; this report) that perhaps as many as 16 (table 3) small pyroclastic eruptions took place episodically in the two million year period prior to the cataclysmic eruption of the Bishop Tuff. Three layers of coarse-grained tephra occur near the Cowan mine, and three similar coarse-grained tephra beds occur at Blind Spring Hill south of Benton Hot Springs, Calif. These tephra beds record episodes of pyroclastic volcanism about 2.1 million years ago. Another layer of coarse-grained tephra near the Cowan mine south of Benton Hot Springs, Calif., records an event of pyroclastic volcanism at about 1.0 m.y. Other pyroclastic volcanic activity occurred about 1.0 m.y. as inferred from the presence of two layers of volcanic ash interlayered in sediments along the Owens River north of Bishop, Calif.

Evidence in the volcanic field and at ash localities in California, Nevada, and Utah implies that ten other pyroclastic eruptions occurred in the Long Valley-Glass Mountain area 2.5 to 1.0 million years ago. That this volcanic activity actually occurred is indicated by numerous layers of ash found in Utah, Nevada, and California that have chemical and mineralogical properties similar to the Bishop Tuff (tables 1 and 3) and the rhyolites of the Glass Mountain. In most instances, these ash and tephra beds can be shown to occupy older stratigraphic positions relative to the Bishop. Sarna-Wojcicki and others (1980) and Izett (1981) discussed certain features of the chemical and mineralogical composition of some of these ash beds and pointed out their mineralogical and chemical affinity with Bishop ash beds.

In addition to the middle Pleistocene and late Pliocene volcanic episodes, small eruptions of silicic tephra occurred in latest Pleistocene and Holocene time (Bailey and others, 1976, p. 735; Wood, 1977) at the Mono-Inyo Craters south of Mono Lake, Calif. Lajoie (1968) reported that the late Pleistocene deposits near Mono Lake, Calif., contain 18 different tephra beds generated during eruptions at Mono Craters.

The pyroclastic materials formed during the many different episodes of rhyolitic volcanism are united by a common set of chemical and mineralogical properties that distinguishes them from tephra generated at other upper Cenozoic volcanic centers of the Western United States (Izett and others, 1970; Sarna-Wojcicki and others, 1980, p. 4; Izett, 1981). Because of the protracted history of pyroclastic eruptions in the Long Valley-Glass Mountain region, it seems probable that more pyroclastic eruptions will occur in the future. The pyroclastic volcanism is the surface manifestation refelecting the buoyant rise into high levels of the crust of a large granitic batholith that has been evolving beneath the Long Valley-Glass Mountain region in late Cenozoic time.

In following sections of this report, the pre-Bishop ash beds are described. Instrumental neutron activation analyses of the glass phases of the ashes are listed in table 3, and locality information, along with pertinent comments, are given in table 4. The ash beds are grouped in table 3 on the basis of similar elemental composition and arranged from youngest to oldest. The stratigraphic arrangement of some of the the ash beds on table 3 is tenuous and, surely, as more information becomes available, their age and stratigraphic relationships will be further clarified and modified.

BLACK CANYON-4 ASH BED

A Pliocene ash bed collected and studied by R. E. Wilcox (written commun., 1971) was named by Izett (1981) the Black Canyon-4. It is the fourth bed from the base in a sequence of six ash beds separated by sediments at Black Canyon, about 14 km southeast of Bishop, Calif. Analyses of the glass shards indicate that it contains considerably less iron and more manganese than Bishop air-fall tephra (tables 1 and 3). Based on a fission-track age of an ash bed that occurs stratigraphically below these two ash beds at Black Canyon (Izett, 1981, table 5, bed 64) and on a K-Ar age of an overlying ash bed (Taylor Canyon-P of Izett, 1981, plate 1, bed no. 38), the Canyon-4 ash bed may be about 2.5 to 2.7 m.y. The source of this ash bed is not known, but based on its chemical composition, it possibly was the Glass Mountain area north of Bishop, Calif.

FRENCHMAN FLAT ASH BED

The Frenchman Flat ash bed was named by Izett (1981, plate 1, no. 47) for an ash at a depth of 195 m (W. J. Carr, written commun., 1978) in a drill hole in Frenchman Flat at the Nevada Test Site. An ash bed (table 3, this report) in a drill hole in Pliocene deposits at Searles Lake, Calif. (Sarna-Wojcicki and others, 1980, table 1, sample 49), and an ash bed (table 3, this report) in the Lathrop Wells 15-minute quadrangle, Nye County, Nev., collected by W C Swadley of the U.S. Geological Survey are correlated with the Frenchman Flat ash bed on the basis of their similar chemical composition (table 3). This ash bed differs from Bishop air-fall tephra because it contains more manganese and less uranium and differs from the Black Canyon-4 ash bed because it contains significantly more iron. A fission-track age determination made by me on glass shards separated from the ash bed in the drill hole at Frenchman Flat, Nev., yielded an age of about 2.2 m.y. Glass fission track ages generally yield only minimum ages owing to track annealing (Naeser and others, 1980), and the ash is certainly much older than 2.2 m.y. W. J. Carr (written commun., 1982) reports that the ash at Frenchman Flat has normal magnetic polarity. Because the ash has normal polarity, it suggests to me that it formed in the age span 2.5-2.9 m.y. during the Gauss normal polarity epoch.

Izett (1981, plate 1) estimated the age of the ash to be about 2.3-2.4 m.y., but because the ash is now known to have normal polarity its age may be older than 2.4 m.y. The source area of this ash bed is not known, but it is suspected to be the Glass Mountain area north of Bishop, Calif., because the glass shards of these ash beds have chemical affinity with Bishop tephra (table 1 and 3).

WAUCOBA ROAD-1 AND WAUCOBA ROAD-2 ASH BEDS

Coarse-grained tephra units in Pliocene sedimentary deposits adjacent to Waucoba Road in the Waucoba Mtn. 15-minute quadrangle, Calif., were named the Waucoba-1 and Waucoba-2 by Izett (1981, plate 1, beds 40 and 39). The glass of these tephras contains significantly more manganese than does Bishop air-fall tephra (tables 1 and 3). Waucoba-1 ash bed contains more cesium, rubidium, tantalum, and uranium than the Bishop; Waucoba-2 contains slightly more tantalum than the Bishop, but less than Waucoba-1 ash bed. The age of the Waucoba-1 and Waucoba-2 ash beds is about 2.2 m.y. as inferred from stratigraphic relationships with other ash beds. The source area of these tephra units is not known, but based on their coarse grain size and their chemical composition, the Glass Mountain area north of Bishop, Calif., seems probable.

TAYLOR CANYON-P, TAYLOR CANYON-C, and TAYLOR CANYON-U ASH BEDS

A group of tephra beds and ashflows, older than the Bishop Tuff, were mapped and named the tuff of Taylor Canyon by Krauskopf and Bateman (1977). These tephra beds are strikingly similar in their chemical and mineralogical properties to ash beds at various localities in California, Nevada, and Utah. Three superposed units of coarse-grained air-fall tephra occur at the Cowan Pumice mine and three similar units occur at Blind Spring Hill south of Benton Hot Springs, Calif. The tuff of Taylor Canyon is presumably part of a complex volcanic unit called the rhyolites of Glass Mountain by Bailey and others (1976, p. 729-730). Izett (1981, p. 10218) named downwind equivalents of two of these tephra units the Taylor Canyon-P and Taylor Canyon-C ash beds, and a third unit is herein informally named the Taylor Canyon-U. However, correlation of ash beds in California, Nevada, and Utah with a specific air-fall tephra unit of the Tuff of Taylor Canyon is extremely tentative because the chemical and mineralogical properties of the three air-fall pumice units are nearly identical.

Taylor Canyon-P ash bed is perhaps equivalent to the lowest of three air-fall pumice units exposed in excavations in the Cowan mine area and the lowest of three air-fall pumice units at the south end of Blind Spring Hill (Tucker, 1927, p. 403-404) near Yellowjacket Canyon, south of Benton Hot Springs, Calif. Ash beds that seemingly correlate with the Taylor Canyon-P ash bed are found southeast of Bishop, Calif., at Black Canyon (sixth ash bed from the base of the ash-bed sequence) and in the Amargosa Valley, Nev., (W. J. Carr, written commun., 1981; table 3, this report). The Taylor Canyon-P ash beds consistently contain less iron and calcium and more manganese, tantalum, cesium, rubidium, and uranium than Bishop air-fall tephra. Taylor Canyon-C ash beds correlate with the second air-fall pumice from the base at Yellowjacket Canyon at the south end of Blind Spring Hill south of Benton Hot Springs, Calif., and a tephra unit in the White Mountain Peak quadrangle north of Bishop, Calif. Taylor Canyon-C ash beds were found near Beaver, Utah, above the Huckleberry Ridge ash bed (previously called the Pearlette type B ash) of Izett and Wilcox (1982) and in the Waucoba Mountain quadrangle southeast of Bishop, Calif. The composition of glass shards of the Taylor

Canyon-C tephra is nearly identical to the composition of glass of the Taylor Canyon-P tephra. The Taylor Canyon-C seemingly contains slightly less cesium and uranium than Taylor Canyon-P, but distinction between these chemically similar tephra units, where stratigraphic control is lacking, is perhaps not always possible. The Taylor Canyon-C tephra was K-Ar dated (sanidine) at 2.1 m.y. by Izett (1981, table 4). The Taylor Canyon-P ash bed, which occurs stratigraphically just below the Taylor Canyon-C ash bed, is probably also about 2.1 m.y.

Coarse-grained tephra that forms the uppermost of three stratigraphically superposed air-fall units at Yellowjacket Canyon at Blind Spring Hill south of Benton Hot Springs, Calif., is here named the Taylor Canyon-U bed. It is similar in chemical composition to the other two Taylor Canyon tephra units except that it apparently contains slightly less uranium. The age of this tephra unit is presumably about 2.1 m.y. because of its stratigraphic nearness to the dated Taylor Canyon-C tephra.

MANIX LAKE-2 AND MANIX LAKE-3 ASH BEDS

Two ash beds separated by only a few meters of Pliocene sediments occur along the banks of the Mojave River at Manix Lake, San Bernardino County, Calif. These ash beds were collected and studied by Merriam and Bischoff (1975) and Sarna-Wojcicki and others (1980) and named by Izett (1981, plate 1, bed nos. 34 and 35). The chemical composition of the glass shards of the ash beds differ from the chemical composition of Bishop air-fall tephra in that they have a higher manganese content (tables 1 and 3). The Manix Lake-2 ash bed contains nearly twice as much uranium, slightly more cesium and rubidium, and less iron than Bishop air-fall tephra. The Manix Lake-3 can be distinguished with confidence from the Manix Lake-2 ash bed by its lower uranium content and differences in the amounts of several other elements. The age of these two stratigraphically close ash beds is probably slightly less than 2.0 m.y. because they overlie an ash, correlated by Sarna-Wojcicki and others (1980, p. 39) with the Huckleberry Ridge ash of Izett and Wilcox (1982), that is 2.0 m.y. The source-area tephra units of these ash beds is not known. Because the glass shards of these ash beds are similar to tephra of the Bishop Tuff and the rhyolites of Glass Mountain of Bailey and others (1976, p. 729-730), the source area for the ash beds may be in the Glass Mountain area north of Bishop, Calif.

LAST CHANCE BENCH ASH BED

An ash bed that lies about 20 m above a Huckleberry Ridge ash bed of Izett and Wilcox (1982) near Beaver, Utah, was named the Last Chance Bench ash bed by Izett (1981, p. 10217-10218). This ash is nearly identical to Bishop air-fall tephra in chemical composition (tables 1 and 3). The age of this ash may be about 1.8 m.y. as judged by its stratigraphic nearness to the underlying well-dated Huckleberry Ridge ash bed (2.0 m.y.). The source-area tephra unit of this ash bed is not known; however, the Glass Mountain area north of Bishop, Calif., seems likely because of the similarity in chemical composition of glass shards of this ash bed and tephra units of the Bishop Tuff and the rhyolites of Glass Mountain of Bailey and others (1976, p. 729-730).

SOUTH MOUNTAIN ASH BED

An ash bed in Pliocene or Pleistocene marine sediments near Ventura, Calif. (Sarna-Wojcicki and others, 1980, p. 36, sample 27) was named by Izett (1981, p. 10217) the South Mountain ash. Although it is nearly identical to Bishop air-fall tephra (table 1 and 3), Sarna-Wojcicki and others (1980)

considered it a separate bed from the Bishop. The glass shards contain slightly more cesium, rubidium, and manganese than the glass phase of Bishop air-fall tephra. Its age is presumably about 1.8-1.2 m.y. based on its assumed stratigraphic realtions with the overlying Bailey ash bed dated about 1.2 m.y. by Izett and others (1974). The source-area tephra unit for this ash bed is not known; however, the Glass Mountain area north of Bishop, Calif., seems likely because of the similarity in chemical composition of glass shards of this ash bed and tephra units of the the Bishop Tuff and the rhyolites of Glass Mountain of Bailey and others (1976, p. 729-730).

BAILEY ASH BED

An ash bed in marine Pliocene sediments of the Pico Formation near Ventura, Calif. (Izett and others, 1974; Sarna-Wojcicki and others, 1980; Izett, 1981, p. 10217), was called the Bailey ash by Yeats and McLaughlin (1970). Glass shards of this ash bed contain significantly more cesium, rubidium, uranium, and manganese than do glass shards of Bishop air-fall tephra (tables 1 and 3). The chemical composition of the Bailey ash is nearly identical to the South Mountain ash as previously pointed out. Based on the analyses at hand (table 3), the Bailey seemingly contains more thorium than the South Mountain; however, the thorium-to-uranium ratio of the South Mountain bed seems anomalous compared to most other ash beds. However, the Bailey does seem to contain less scandium than the South Mountain. The age of the Bailey ash was determined by Izett and others (1974) to be about 1.2 m.y. The source-area tephra unit for this ash bed is not known; however, the Glass Mountain area north of Bishop, Calif., seems likely because of the similarity in chemical composition of glass shards of this ash bed and tephra units of the rhyolites of Glass Mountain of Bailey and others (1976, p. 729-730).

GLASS MOUNTAIN-G AND GLASS MOUNTAIN-D ASH BEDS

Two chemically similar ash beds occur in sediments about 17 m below the Bishop Tuff about 7 km north of Bishop, Calif. The ash beds are separated by 6 m of sediments and lie below the Matuyama and Brunhes paleomagnetic boundary, according to Sarna-Wojcicki and others (1980, p. 29-31). These ash beds were named the Glass Mountain-G and Glass Mountain-D by Izett (1981, p. 10217). Another ash bed suspected to be a Glass Mountain-G or a Glass Mountain-D ash bed occurs about 10 m below the Bishop ash bed in sediments of ancient Lake Tecopa near Shoshone, Calif. (Sheppard and Gude, 1968, fig. 6). The chemical composition of these two ash beds is nearly identical to that of Bishop air-fall tephra, and the ability to confidently distinguish them from the Bishop, based on the chemical data at hand, may not be possible. Of equal importance, the mineralogy and the chemical composition of the phenocrysts in the Glass Mountain-G and Glass Mountain-D ash beds are also nearly identical to those in Bishop air-fall tephra. Although the ash beds may not be distinguished from Bishop ash beds on the basis of chemical composition and mineralogy, the Glass Mountain ash beds should have reverse paleomagnetic polarity, whereas the Bishop has normal magnetic polarity. Primary air-fall tephra units suspected to be the source-area equivalents of the Glass Mountain-D ash beds occur in the Glass Mountain area north of Bishop, Calif. (table 3 and table 4). The correlation of the Glass Mountain-G and Glass Mountain-D ash beds with tephra of the rhyolites of Glass Mountain of Bailey and others (1976, p. 729-730) seems likely because of the similarity in the chemical composition of glass shards and the assemblage of microphenocrysts for the ashes and the ryholites of Glass Mountain.

MILLERTON LAKE ASH BED

A rhyolitic ash bed included in the Pleistocene Friant Pumice Member of the Turlock Lake Formation by Janda (1965) occurs near Friant, Calif., (MacDonald, 1941; Trauger, 1950). The ash bed has been mined by the California Industrial Minerals Company for more than 20 years. In the mine workings, the stratigraphic relationship between the ash and the enclosing sediments is well exposed. As seen in the walls of the mine, the ash bed is unconformably overlain by a unit of pumiceous conglomerate (Chesterman, 1956, p. 38, fig. 21). Many of the cobbles in the conglomerate unit are composed of several types of stream-rounded volcanic rock including fresh, light-weight rhyolite pumice and dense, rhyolite welded tuff. The welded tuff cobbles strongly resemble welded tuff of the Bishop (fig. 5) at its type area north of Bishop, Calif.

The bed of fine-grained volcanic ash within the Friant Pumice Member at the excavations of the California Industrial Minerals mine is here named the Millerton Lake ash bed. The ash is named for Millerton Lake which lies a few kilometers from the California Industrial Minerals mine. Millerton Lake, rather than Friant, was chosen to prevent confusion that might arise from using the name Friant for both the ash bed and for the formally named Friant Pumice Member. The chemical composition of the glass of the Millerton Lake ash is much like that of Bishop air-fall tephra (tables 1 and 3). However, the Millerton Lake ash differs in that it has slightly less iron than the Bishop. Perhaps the Millerton Lake ash bed is a slightly different variety of Bishop ash, but more analyses of the ash are needed to determine if the small difference in iron content is consistently different than the Bishop air-fall tephra.

Sarna-Wojiciki and others (1980, table 1, sample no. 1) obtained chemical analyses of pumice cobbles from the conglomerate unit that overlies the Millerton Lake ash bed and drew attention to their similarity in composition with pumice of the Bishop Tuff (see also table 3, this report). Because of small differences in the chemical composition (lanthanum and cerium) of the glass of the pumice cobbles in the Friant Pumice Member and glass of pumice of the air-fall unit of the Bishop Tuff, Sarna-Wojcicki and others (1980, p.18-19) suggested that the cobbles represent a slightly different chemical type of Bishop tephra called the Friant type.

The age of the Millerton Lake ash bed has not been established by isotopic methods. However, pumice cobbles in the conglomerate unit that unconformably overlies the ash bed at the California Industrial Minerals mine near Friant, Calif., were dated by the K-Ar method (Janda, 1965, p. 131; Dalrymple, 1980) at about 0.62 m.y. Sarna-Wojcicki and others (1980, p. 21-23) considered the K-Ar age of 0.62 m.y. for the pumice cobbles to be anomalous because the chemical composition of the cobbles (their Friant-type Bishop ash) is strikingly similar to tephra of the 0.74 m.y. Bishop Tuff.

To further explore the K-Ar ages of the pumice cobbles, three groups of cobbles were collected by me from the conglomerate unit, and sanidine separated from them was dated (table 9). Sanidine separated from one group of pumice cobbles gave a K-Ar age of 1.78±0.03; sanidine from another group gave an age of 1.06±0.02 m.y.; and sanidine from a third group gave an age of 0.19±0.3 m.y.

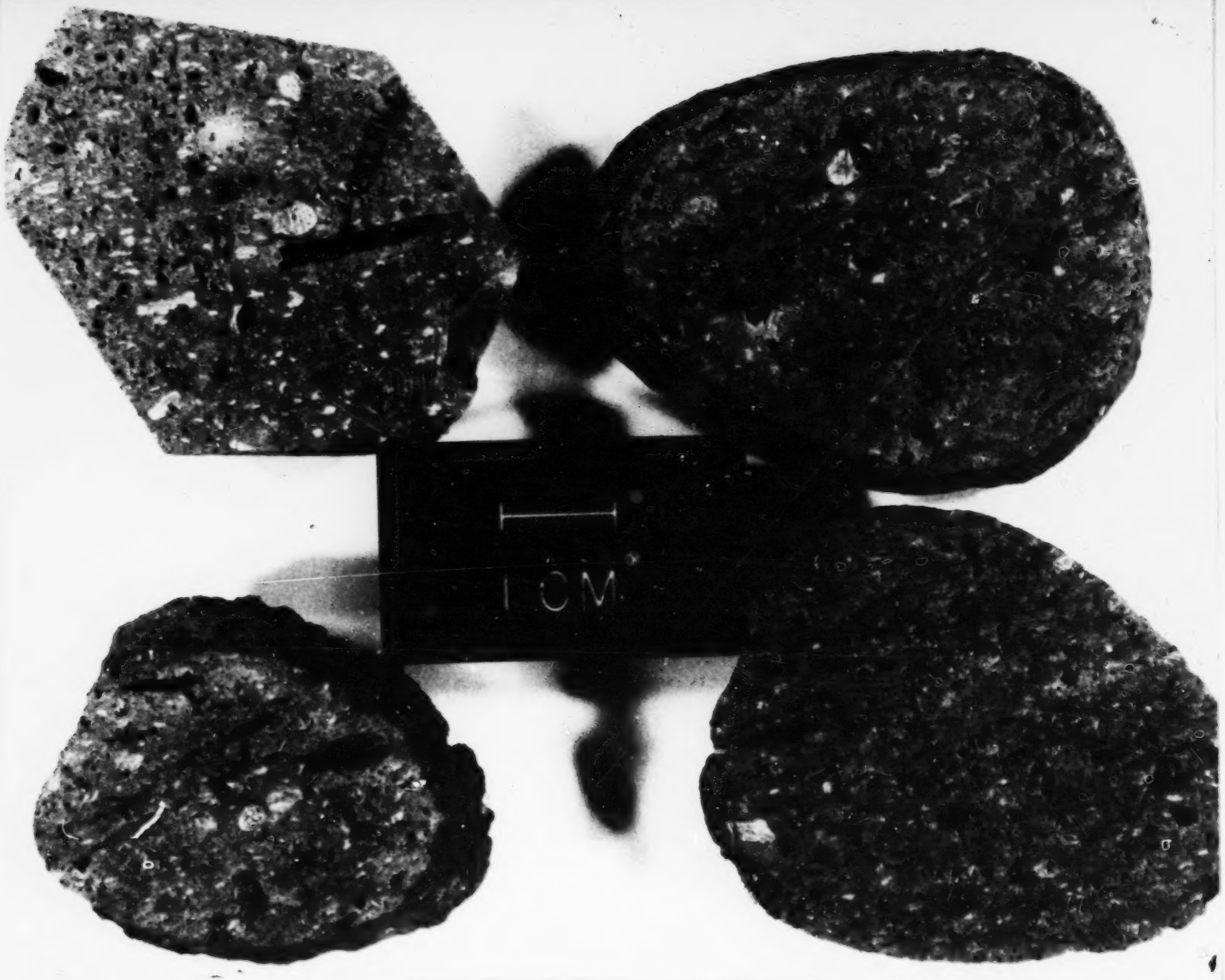

Figure 5.--Photograph of stream-rounded cobbles of welded tuff (Bishop Tuff?) collected from conglomerate unit that lies unconformably on the Millerton Lake ash bed at the California Industrial Minerals mine near Friant, Calif. Cobbles have fairly well-developed eutaxitic structure. Xenolith of metamorphic rock of Sierran(?) age is in cobble in upper left corner of photograph.

The wide spread of K-Ar ages of the pumice cobbles reported here and of K-Ar ages reported by Dalyrymple (1980) is very puzzling in view of the observation that the chemical composition and mineralogy of some pumice cobbles are nearly identical to the 0.74 m.y. Bishop Tuff tephra. One explanation for the wide spread of ages is that the K-Ar ages older than the Bishop result from dating random mixtures of pre-Bishop pumice cobbles, all of which chemically and mineralogically resemble Bishop tephra. Another possibility that could explain the older K-Ar ages is that some cobbles, assumed to be pumice, may actually have been nonwelded tuff cobbles containing undetected xenoliths of markedly older Sierran age granitic rocks. However, precautions were taken to exclude tuff cobbles by only selecting cobbles (greater than 1 cm in diameter) that would float in water.

Another condition that can result in unrealistically old potassium-argon ages occurs when significantly older (2-3 orders of magnitude) detrital potassium feldspar grains lodge in tubular vesicles in pumice cobbles while they are being transported by sediment-laden streams and rivers. Various amounts of these older potassium feldspar grains can be retained in sanidine concentrates separated from the pumice cobbles. The older detrital potassium feldspar grains cannot be removed during heavy-liquid separations and can only be removed by hand picking. A potassium-argon age obtained from a mixture of primary sanidine and significantly older detrital potassium feldspar obviously will be incorrect. The oldest potassium-argon age (1.78 m.y.) was obtained on pumice cobbles which had been ultrasonically scrubbed in dilute hydrofluoric acid. Although this treatment may have removed detrital feldspar grains from the surface of the pumice, it coud not remove detrital feldspar grains deeply lodged in vesicular tubes in some pumice cobbles. A second group of cobbles was prepared by grinding or sawing about 1-2 cm from the outer parts of the pumice cobbles so as to increase the possibility of dating only primary phenocrystic sanidine from the interiors of the cobbles. The potassium-argon age of sanidine from this group of pumice cobbles yielded an age of 1.06 m.y. This age is similar to the potassium-argon age of pumice of the rhyolites of Glass Mountain (Izett, 1981, table 4, DKA- 3811) which have a chemical composition similar to the Bishop Tuff.

The potassium-argon age (0.19 m.y., table 9) of sanidine separated from a third group of pumice cobbles seems to be anomalously young considering the middle Pleistocene age of the Friant Pumice Member of the Turlock Lake Formation (Janda, 1965). Only a small amount of sanidine was available for this determination, and the amount of radiogenic ^{40}Ar obtained, relative to the total ^{40}Ar extracted (table 9), was small (2.4 percent). Naeser and others (1981, p. 30-31) recently emphasized the unreliabilty of K-Ar ages having a low ratio of radiogenic ^{40}Ar to total ^{40}Ar.

In summary, the spurious K-Ar ages of pumice cobbles from the conglomerate unit in the Friant Pumice Member of the Turlock Lake Formation provide little information on the age of the underlying Millerton Lake ash bed. Perhaps there are several age groups of pumice cobbles in the conglomerate unit. In contrast to the isotopic age data, stratigraphic relationships clearly show that the Millerton Lake ash bed is older than the overlying conglomerate unit that contains stream-rounded fragments of welded tuff here assigned to Bishop Tuff. Remnants of a once more extensive lobe of the Bishop Tuff (formerly called the tuff of Reds Meadow) are found on the west side of the Sierra Nevada crest in the drainage of the Middle Fork of the

San Joaquin River (Huber and Rinehart, 1965; Hildreth, 1977, p. 296). Considerable time (10,000 years??) may have lapsed following the emplacment and welding of the Bishop ash-flow sheet at 0.74 m.y. and the subsequent reintegration of the San Joaquin River drainage system to allow incision of the Bishop and accompanying transportation of welded tuff fragments of the Bishop to the Friant, Calif., area.

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Table 2. List of localities of the Bishop Tuff and Bishop ash beds giving pertinent stratigraphic and other information

[Localities are listed in alphabetic order, first by State and then by County, and number keyed to the map showing the distribution of the ashes. Most sample numbers refer to collections of ash made by G. A. Izett (74G3) or by R. E. Wilcox (68W156) giving the year and sample number. Other sample numbers refer to collections of ash made by other geologists. Leaders (---) indicate sample currently not available to the writer; closely spaced sample localities given same locality number]

Loc. No. fig. 1	Sample Nos.	County	Location and quadrangle	Remarks
			Bishop Tuff	
			California	
1	64W96, 79G14 79G75, 79G77 79G78, 79G81 79G82, 79G83 80G23, BT-8	Inyo	NW1/4 NE1/4 sec. 4, T. 6 S., R. 33 E.; Bishop 15-minute	Pumice lapilli from 4-m-thick air-fall unit at the base of the Bishop Tuff at the Industrial Minerals quarry (abandoned) 10 km north of Bishop, Calif. (Tucker, 1927; Bateman, 1953; Chesterman, 1956, p. 35 and fig. 16; Dalrymple and others, 1965, sample no. 4G001; Izett and others 1970, loc. 1; Sarna-Wojcicki and others, 1980, table 3, no. 8).
1	79G15, 79G79A 79G80, 79G84, 80G21	Inyo	NW1/4 NE1/4 sec. 4, T. 6 S., R. 33 E.; Bishop 15-minute	Rounded pumice cobbles from the lowest part of the main thick ash-flow at the Industrial Minerals pumice quarry 10 km north of Bishop, Calif.; sample no. 80G21 is from a thin lenticular ash flow that underlies the main, thick ash flow (see fig. 2).
2	79G21	Inyo	SW1/4 SW1/4 sec. 20, T. 6 S., R. 32 E.; Bishop 15-minute	Pumice lapilli from about the middle of the basal, air-fall unit of the Bishop Tuff at cliff exposures along the Owens River; same locality as sample B-93 of Sarna-Wojcicki and others (1980, table 7, p. 45).
3	79G85	Inyo	SE1/4 sec. 14, T. 8 S., R. 33 E.; Bishop 15-minute	Pumice lapilli from air-fall unit at the base of the Bishop Tuff.
3	79G86	Inyo	SE1/4 sec. 14, T. 8 S., R. 33 E.; Bishop 15-minute	Pumice lapilli from basal unit of ash-flow tuff of the Bishop(?) Tuff (significantly different Fe content of glass than other air-fall Bishop Tuff samples (see table 1).
4	64W109	Mono	NE1/4 SE1/4 sec. 10, T. 2 S., R. 31 E.; Glass Mountain 15-minute	Pumice lapilli from a prospect trench in the basal, air-fall unit of the Bishop Tuff about 1.6 km southwest of Benton Hot Springs, Calif.; just west of California State Highway 121.
5	J-328	Madera	see Sarna-Wojcicki and others, 1980 for location; Devils Postpile 15-minute	Air-fall pumice from base of ignimbrite previously called the tuff of Reds Meadow; now assigned to the Bishop Tuff (see Hildreth, 1977, p. 296).
6	69W140	Mono	SE1/4 NW1/4 sec. 34, T. 4 S., R. 30 E. Casa Diablo Mountain 15-minute	Pumice lapilli from the basal, air-fall unit of the Bishop Tuff in roadcut along U.S. Highway 395.
7	79G88	Mono	NW1/4 sec. 25, T. 1 S., R. 29 E.; Glass Mountain 15-minute	Pumice blocks 0.5 m in diameter from ash-flow tuff of the upper, pyroxene-bearing part of the Bishop Tuff; near locality B-138 of Hildreth (1977, p. 299).
7	79G94	Mono	NE1/4 sec. 27, T. 1 S., R. 29 E.; Glass Mountain 15-minute	Pumice block about 1.0 m in diameter from ash-flow tuff of the upper, pyroxene-bearing pumice part of the Bishop Tuff; near locality B-137 of Hildreth (1977, p. 299).

California

8	68W156 74G3	Inyo	SE1/4 SW1/4 sec. 29, T. 22 N., R. 7 E.; Shoshone 15-minute	15-cm-thick ash in sediments of Pleistocene Lake Tecopa exposed at road level about 1.9 km east of Shoshone, Calif., along the road to Pahrump, Nev.; same locality as that of Sheppard and Gude (1968, p. 13, no. 3); other localities of Bishop ash are in nearby areas such as in the NW1/4 sec. 30, T. 22 N., R. 7 E. along the west side of a road in the northern part of Shoshone, Calif.; a Lava Creek B ash bed (previously called Pearlette type O ash) is about 6 m above the Bishop ash bed in the area; see Izett and others (1970, p. 130, no. 3) and Borchardt and others (1972); see also Hillhouse and Cox (1976) for descriptions of the magnetostratigraphy of the Pleistocene deposits of Lake Tecopa; Sarna-Wojcicki and others (1980, table 1, sample no. 9) listed chemical analyses of the ash.
9	---	Imperial	NW1/4 SW1/4 sec. 19, T. 9 S., R. 12 E.; Durmid 7 1/2-minute	2-m-thick composite ash bed; consists of reworked, water-redeposited ash and thin silt beds; described by Sarna-Wojcicki and others (1980, table 1, sample nos. 6, 7, 12, and 15); another locality of ash assigned to the Bishop ash bed by Merriam and Bischoff (1975, p. 210, loc.1) occurs in NW1/4 sec. 34, T. 8 S., R. 11 E.
10	70W4	Kings?	Precise locality unknown to authors	Ash from borehole at a depth of 165 m in the Corcoran Clay Member of the Turlock Lake Formation (R. J. Janda of the U.S. Geological Survey, written commun., 1970).
11	---	Kern	About 16 km northwest of Wasco, Calif. (P. D. Davis of Fugro Inc., written commun., 1979)	Thin volcanic ash at a depth of 84 m in borehole H-35 in the Turlock Lake Formation (Pleistocene); locality described by Davis and others (1977, p. 385); they reported a K-Ar age of 0.942 ±0.010 m.y. for the ash (glass shards only?); this ash identified by Davis and others (1977) as a Bishop ash bed; A. M. Sarna-Wojcicki (written commun., 1981) recognized that the ash is not a Bishop ash because the chemical composition and index of refraction and shape of glass shards of a sample of the ash do not match other Bishop ash beds.
12	---	Riverside	SW1/4 NW1/4 sec. 7, T. 7 S., R. 3 W.; Riverside 7 1/2-minute	In Pleistocene alluvium in the Chanmey Hills; locality information and chemical analyses of the ash given by Sarna-Wojcicki and others (1980, table 1, sample no. 10); they (1980, p. 29) state that this locality is ..."at or close to..." another locality of ash identified and listed by Merriam and Bischoff (1975, p. 210, loc. 6) as Bishop ash.
13	---	Riverside	SE1/4 sec. 17, T. 6 S., R. 9 E.; Thermal Canyon 7 1/2-minute	Ash bed in fine-grained sandstone and siltstone of the Palm Spring Formation (Pliocene and Pleistocene); identified as Bishop ash by Merriam and Bischoff (1975, p. 210, loc. 2).
14	---	Riverside	SE1/4 SW1/4 sec. 32, T. 6 S., R. 3 E.; Idylwild 15-minute	In Pleistocene alluvium in the Anza-Borrego area; see Sarna-Wojcicki and others (1980, table 1, sample no. 11) for locality information and chemical analyses of the ash; Sarna-Wojcicki and others (1980, p. 29) report that this ash locality is at or close to another locality of ash identified by Merriam and Bischoff (1975, p. 210, loc. no. 4) as a Bishop ash.

15	---	Riverside	W 1/2 sec. 30, T. 3 S., R. 16 E.; Coxcomb 15-minute	Ash bed in dissected alluvial fan; identified as Bishop ash by Merriam and Bischoff (1975, p. 210, loc. no. 7).
16	---	San Bernardino	NE1/4 sec. 1, T. 10 N., R. 4 E.; Newberry 15-minute	Ash in alluvial fan; identified by Merriam and Bischoff (1975, p. 210, loc. no. 8) as Bishop ash.
17	---	San Diego	NW1/4 NE1/4 sec. 24, T. 9 S., R. 5 E.; Clark Lake 15-minute	In fluvial Pleistocene sediments in Anza-Borrego area; locality data and chemical analyses of ash given by Sarna-Wojcicki and others (1980, table 1, sample no. 5); according to them (1980, p. 29), this ash locality is at or near one identified by Merriam and Bischoff (1975, p. 210, loc. no. 3) as Bishop ash.
18	---	San Diego	Sec. 20, T. 10 S., R. 3 E.; Warner Springs 7 1/2-minute	Ash in sediments of Warner Basin; identified as Bishop ash by Merriam and Bischoff (1975, p. 210, loc. no. 5).
19	---	Tulare	NW1/4 NE1/4 sec.16, T. 23 S., R. 24 E.; Alpaugh 7 1/2-minute	From a Bureau of Reclamation borehole; locality information and chemical analyses of the ash given by Sarna-Wojcicki and others (1980, table 1, sample no. 2).
20	---	Ventura	lat 34° 17′ 56′′N., long 119° 16′ 58′′W.; Ventura 7 1/2-minute	Interbedded in Santa Barbara Formation near Ventura, Calif.; another locality of Bishop ash is at lat 34° 17′ 57′′N., long 119° 15′ 48′′W.; locality information and chemical analyses given by Sarna-Wojcicki and others (1980, table 1, sample nos. 3 and 4).
			Colorado	
21	65W131	Chaffee	SW1/4 SW1/4 sec. 9, T. 51 N., R. 78 W.; Poncha Springs 15-minute	0.3-m-thick impure ash in roadcut (west side) of U.S. Highway 285 near Centerville Cemetary; in overbank silt overlying river gravel of Pleistocene terrace deposit of Arkansas River; in Nebraskan(?) age alluvium of Scott and others (1975); gravel no. 2 of Van Alstine (1969, p. 23); 80 m above modern flood plain of the Arkansas River; a Lava Creek B ash (named Pearlette Type O by Izett and others in 1970) is in the next lower (younger) terrace; see Izett and others (1970, p. 131, loc. no. 9).
22	65W1	Montrose	SE1/4 NW1/4 sec. 26, T. 48 N., R. 19 W.; Roc Creek 7 1/2-minute	0- to 8-cm-thick impure ash in Pleistocene deposits in the northern part of Paradox Basin; about 3.2 km northeast of Paradox, Colo.; see Cater (1970, p. 49).
23	80W90	Alamosa	E1/2 sec. 10, T. 36 N., R. 11 E.; Alamosa West 7 1/2-minute	0- to 5-cm-thick lens of ash interbedded in the Alamosa Formation (Pleistocene) at Hansen Bluff along the Rio Grande River southeast of Alamosa, Colo.; sample submitted by Karel Rogers of Adams State College (written commun., 1980).
24	80W92	Saguche	SE1/4SE1/4 sec. 32, T. 45 N., R. 32 E.; Mirage 7 1/2-minute	Impure ash in Pleistocene fan deposit; ash smeared out in fault zone separating fan deposit from bedrock; minimum post-Bishop ash (0.74 m.y.) fault movement about 10 m; collected by S. M. Colman of the U.S. Geological Survey.
			Idaho	
25	78W218 78W217	Bannock	NE1/4 sec. 33, T. 12 S., R. 38 E.; Oxford 15-minute	Interbedded in pre-Lake Bonneville fan deposit of middle Pleistocene age; a Lava Creek B ash is stratigraphically above; locality southeast of Red Rock Pass 1 km from where power lines cross gully; another Bishop ash is nearby in the NW1/4 sec. 33, T. 12 S., R. 38 E. in pre-Lake Bonneville fan deposits beneath a $CaCO_3$ zone; locality at top of gully north of house in NW1/4 sec. 33, T. 12 S., R. 37 E.; collected by R. C. Bright of the University of Minnesota (written commun., 1979).

26	78W17	Bingham	NW1/4 SE1/4 sec. 11, T. 4 S., R. 37 E.; Yandell Springs 15-minute	0.5-m-thick impure ash interbedded in Pleistocene loess-like silt; three other ash beds occur stratigraphically above; one of the three ash beds is a Lava Creek B ash bed; at Ash Hill north of the Gay Mines on the west side of haulage road; collected by, and locality information from, K. L. Pierce of the U.S. Geological Survey (written commun., 1978).
			Nebraska	
27	66W8 71W9	Nuckolls	NE1/4 SE1/4 sec. 26, T. 3 N., R. 8 W.; Mount Clare 7 1/2-minute	0.7-m-thick ash in the Pleistocene Sappa Formation of Miller and others (1964, p. 79).
			Nevada	
28	---	Mineral	NE1/4 NW1/4 sec. 24, T. 12 N., R. 28 E.; Schurz 15-minute quadrangle	Ash in cobble gravel about 6.5 km south of Schurz, Nev.; assigned to the Bishop ash bed by Davis (1977, p. 100, sample no. JOD26).
29	70W19 70W23-70W27	Esmeralda	NE1/4 NE1/4 sec. 17, T. 2 S., R. 40 E.; Silver Peak 15-minute	Pumice lapilli from a borehole at a depth of 104-107 m; borehole just north of Angel Island; sample submitted by R. Nelson of the Foote Creek Mineral Co. (written commun., 1970).
30	78G203	Nye	lat 36° 51′ N., long 116° 19.5′ W.; Jackass Flats 7 1/2-minute	0.3-m-thick ash in Pleistocene alluvium; collected by A. G. Gordon of Fenix and Scisson Co. and W. J. Carr of the U.S. Geological Survey (written commun., 1978); sample no. TSV132-78.
31	79W61	Nye	NW1/4 SE1/4 sec. 26, T. 15 S., R. 50 E.; Lathrop Wells 15-minute	0.5-m-thick ash interbedded in Pleistocene eolian sand unit; collected by W C Swadley of the U.S. Geological Survey (written commun., 1979).
31	79G4	Nye	NE1/4 NE1/4 sec. 21, T. 15 S., R. 50 E. Striped Hills 7 1/2-minute	1-m-thick impure ash in Pleistocene alluvium; locality found by W C Swadley.
32	79W92	Nye	lat 36° 53′ N., long 116° 22.5′ W.; Topopah Spring 7 1/2-minute	0- to 0.5-m-thick ash in Pleistocene alluvium on the east; side of Fortymile Canyon; locality found by A. G. Gordon (written commun., 1979); sample no. AG 109-36.
33	80W70 80W71	Nye	lat 36° 43.5′ N., long 116° 36′ W.; Big Dune 15-minute	Ash in Pleistocene eolian sand; two closely-spaced localities found by W. J. Carr (written commun., 1980); sample nos. SW11-80 and SW12-80) collected by W C Swadley (Swadley, 1982).
			New Mexico	
34	71W25-71W28 73W101	Dona Ana	NW1/4 NW1/4 sec.15, T. 18 S., R. 2 W.; Rincon 7 1/2-minute	0.3-m-thick ash in the Camp Rice Formation(?); in gully about 60 m west of railroad mile post 1074 near Grama Siding of the Santa Fe Railroad; 8 km north of Rincon, N. Mex.; collected by J. W. Hawley of the New Mexico Bureau of Mines and Mineral Resources.
35	70W156 71W29-71W32	Dona Ana	SW1/4 NE1/4 sec. 28, T. 26 S., R. 4 E.; Rincon 7 1/2-minute	0- to 15-cm-thick ash in the piedmont slope facies of the Camp Rice Formation; interlayered in a sand unit in fanglomerate; exposed in 1970 in a pipeline trench about 1 km west northwest of Anthony Gap; collected by R. G. Dickinson of the U.S. Geological Survey; recollected by J. W. Hawley.

36	75L61 80G15 80G16	Beaver	SW1/4 NW1/4 sec. 23, T. 27 S., R. 9 W.; Adamsville 15-minute	About 3 m-thick-ash bed overlying coarse-grained alluvium; xenolithic pumice lumps as large as 10 cm in diameter composed of the rhyolite of the Mineral Mountains K-Ar dated at about 0.5 m.y. by Izett (1981, table 4) occur in the upper part of ash bed; see Lipman and others (1978, p. 141).
37	---	Box Elder	SE1/4 SW1/4 sec. 1, T. 6 N., R. 6 W.; Pokes Point 7 1/2-minute	Ash bed exposed in a borrow pit of the Southern Pacific Railroad Co. pit no. 2 in Little Valley; ash assigned to the Bishop ash by Eardley and others (1973, p. 213); a Lava Creek B ash bed occurs stratigraphically higher to the northeast in the pit according to H. D. Goode of the University of Utah (written commun., 1975); see also (Nash and Smith, 1977, table 4, no. 18).
38	65W5 78G197	Grand	SE1/4 NE1/4 sec. 26, T. 24 S., R. 24 E.; Polar Mesa 15-minute	1-m-thick ash bed in the lower member of the Harpole Mesa Formation of Richmond (1962, p. 34); see Izett and others (1970, p. 131, no. 7b); see Sarna-Wojcicki and others (1980, table 1, no. 16) for analyses of the ash; see also (Nash and Smith, 1977, table 4, no. 25).
39	79G39	Millard	NW1/4 NW1/4 sec. 24, T. 15 S., R. 7 W.; Rain Lake 7 1/2-minute	About 30-cm-thick ash bed interbedded in Pleistocene alluvium exposed about 70 m from the west end of an exploratory trench dug in 1979; ash about 2 m below land surface; sample submitted by R. Patterson of Dames and Moore; samples of the ash recollected by C. D. Miller and W. E. Scott of the U.S. Geological Survey; a fission-track age determined on zircon from the ash is 0.73±0.13 (2 sigma) m.y. (C. W. Naeser of the U.S. Geological Survey, written commun., 1979).
40	79W84	Millard	NE1/4 NE1/4 sec. 32, T. 20 S., R. 12 W.; Long Ridge SW 7 1/2-minute	3- to 5-cm-thick ash bed in Pleistocene deposits; collected by C. G. Oviatt of the University of Utah and W. E. Scott of the of the U.S. Geological Survey (written commun., 1979); locality is just south of Miller Canyon Reservoir.
41	75W58 78G158 78G159	Millard	SW1/4 sec. 31, T. 25 S., R. 6 W.; Cove Fort 15-minute	About 0.3-m-thick ash bed in Pleistocene fan deposits in borrow pit; separated from an overlying tephra bed called the Ranch Canyon ash bed (Izett, 1981) by about 10 m of sediments.
42	79W101	Millard	NW1/4NW1/4 sec. 23, T. 24 S., R. 10 W.; Black Rock 7 1/2-minute	15-cm-thick ash overlying basalt K-Ar dated 1.1 m.y. according to M. N. Machette and T. A. Steven of the U.S. Geological Survey (written commun., 1979).
43	S-28	Salt Lake	SW1/4 SE1/4 sec. 28, T. 1 N., R. 2 W.; Saltair 7 1/2-minute	Ash bed in core from borehole in sediments of Pleistocene Lake Bonneville at a depth of 175 m; identified as Bishop ash by Eardley and others (1973, p. 213) on the basis of electron microprobe analysis of glass shards; location of borehole provided by H. D. Goode (written commun., 1977); see (Nash and Smith, 1977, table 4, no. 22).
43	---	Tooele	Near Burmester, Utah Burmester 7 1/2-minute	Ash bed in core from borehole (Burmester) in sediments of Pleistocene Lake Bonneville at a depth of 86 m; ash identified as Bishop ash on the basis of electron microprobe analysis of glass shards reported by Eardley and others (1973, p. 213); a Lava Creek B ash occurs about 10 m higher in core of the borehole; see Nash and Smith, 1977, table 4, no. 19).

43	57P129 57P133	Salt Lake	SW corner sec. 24, T. 1 N., R. 3 W.; Saltair 7 1/2-minute	Ash bed in core from borehole (Saltair) in sediments of Pleistocene Lake Bonneville; from 197 m depth in borehole; a Lava Creek B ash bed occurs about 31 m above in core; sample submitted by A. J. Eardley of the University of Utah; see also Eardley and Gvosdetsky (1960) for descriptions of the core; see Izett and others (1970, p. 131-132, no. 5b); see also Nash and Smith (1977, table 4, nos. 20 and 23).
44	N-46	Tooele	About 11 km east of Wendover, Utah; No topographic map available	Ash bed in sediments of Pleistocene Lake Bonneville in drill hole at a depth of 99 m; collector, A. J. Eardley; see Izett and others (1970, p. 130, no. 4) and Nash and Smith (1977, table 4, no. 19).
45	64W130 67W161 80G18	Utah	SW1/4 NW1/4 sec. 35, T. 9 S., R. 2 E.; Santaquin Peak 15-minute	0- to 2-m-thick bed in Pleistocene deposits; a Lava Creek B ash occurs 0.3 to 0.5 m stratigraphically above about 1 km north of pond in a deep gully; another locality of Bishop ash occurs in the deep gully just below a pond; see Izett and others (1970, p. 131, no. 6); see also Nash and Smith (1977, table 4, no. 26).
			Wyoming	
46	66W50 74W24-74W25 77G122	Albany	Center sec. 6, T. 14 N., R. 74 W.; Hutton Lake 7 1/2-minute	0- to 0.3-m-thick ash interbedded in silt and sand of terrace alluvium along the west bank of the Laramie River; about 13 m above the modern flood plain of the river; at the Monolith Cement Co. quarry; collected by Brainerd Mears Jr. of the University of Wyoming and R. E. Wilcox of the U.S. Geological Survey.

Table 4.--List of localities of Pliocene and Pleistocene rhyolite tephra units of the Long Valley-Glass Mountain area and some volcanic ash beds in California, Nevada, and Utah suspected to be their correlatives

[Localities are listed in the order given in table 3; most sample numbers refer to collections of ash made by G. A. Izett (74G3) or by R. E. Wilcox (68WI56) giving the year and sample number.

Sample Nos.	County and State	Location and quadrangle	Remarks
79G73A 63cj26	Madera, Calif.	NW1/4 sec. 6, T. 11 S., R. 21 E.; Millerton Lake 7 1/2-minute	Pumice cobbles from a unit of conglomerate that unconformably overlies a 3-m-thick ash bed at the California Industrial Minerals mine near Friant, Calif.; stream-rounded cobbles of welded and nonwelded Bishop Tuff as well as other cobbles of granitic and volcanic rocks also occur in unit.
70W1 79G74	Madera, Calif.	NW1/4 sec. 6, T. 11 S., R. 21 E.; Millerton Lake 7 1/2 minute	Millerton Lake ash bed; very fine grained volcanic ash from a 3-m-thick bed that underlies the conglomeratic unit described above; ash here named the Millerton Lake ash bed for exposures of the ash bed currently being mined at the California Industrial Minerals mine near Friant, Calif.; the iron content of the glass of this ash is significantly less than that of the air-fall pumice of the Bishop Tuff and Bishop ash beds.
79G12	Mono, Calif.	NE1/4 NE1/4 sec. 23, T. 2 S., R. 31 E.; Glass Mountain 15-minute	Pumice blocks from a pit excavated in near the Cowan pumice mine; sanidine from large pumice fragments dated by the K-Ar method at 1.06±0.01 m.y. (Izett, 1981, table 4); glass composition of the pumice nearly identical to the composition of pumice of the basal air-fall unit of the Bishop Tuff and Bishop ash beds; possibly equivalent to the Glass Mountain-D ash bed of Izett (1981, plate 1, bed no. 16).
79G87	Mono, Calif.	SE1/4 NE1/4 sec. 3, T. 5 S., R. 33 E.; White Mountain Peak 15-minute	Pumice lapilli from the middle of an air-fall pumice unit in a pumice pit at the Sacramento mine; questionably assigned to the Bishop Tuff by Hildreth (1977, p. 296); iron content of the glass of pumice abnormally high as compared to the iron content of glass of the air-fall pumice of the Bishop Tuff and Bishop ash beds (see table 1); questionably here grouped with the Glass Mountain-D ash beds; similar in iron content to glass of pumice lumps in ashflow at locality 2 of table 2 (sample 79G86).
75W42	Inyo, Calif.	E1/2 sec. 21, T. 6 S., R. 32 E.; Bishop 15-minute	Volcanic ash interbedded in Pleistocene sediments below the Bishop Tuff; in roadcut adjacent to the Owens River; same locality as that of Sarna-Wojcicki and others (1980, sample 17 and 18, p. 29); glass composition of the pumice nearly identical to the glass composition of pumice of the basal air-fall unit of the Bishop Tuff and Bishop ash beds; probable source-area tephra for the Glass Mountain-D ash bed of Izett (1981).
68WI55	Inyo, Calif.	NW1/4 NW1/4 sec. 31, T. 22 N., R. 30 E. Shoshone 15-minute	Volcanic ash in sediments of Pleistocene Lake Tecopa; about 9 m stratigraphically below a Bishop ash bed; here assigned to the Glass Mountain-D ash bed of Izett (1981).
79G91	Inyo Calif.	SW1/4 sec. 6, T. 1 S., R. 30 E.; Glass Mountain 15-minute	Pumice lapilli from excavations in pumice along Adobe Creek near the mouth of Taylor Canyon; mapped as the tuff of Taylor Canyon by Krauskopf and Bateman (1977); probable source-area tephra of the Glass Mountain-D ash bed.
BT1	Inyo, Calif.	NE1/4 NE1/4 sec. 23, T. 6 S., R. 32 E.; Bishop 15-minute	Volcanic ash interbedded in Pleistocene sediments that underlie the Bishop Tuff; about 6 m below the Glass Mountain-D ash bed of Izett (1981) according to Sarna-Wojcicki and others (1980, samples 17 and 18, p. 29); glass composition nearly identical to that of the basal air-fall unit of the Bishop Tuff; type locality of the Glass Mountain-G ash bed of Izett (1981, plate 1, bed no. 17).

Pico4 70-0-68 70-0-69 70-0-70	Ventura, Calif.	NW1/4 SE1/4 sec. 21, T. 3 N., R. 20 W.; Moorpark 7 1/2-minute	Volcanic ash about 5 cm thick in the Pico Formation of Pliocene and Pleistocene age at Balcom Canyon near Ventura, Calif.; see Sarna-Wojcicki and others (1980) for other chemical analyses of this ash; called the Bailey ash bed by Yeats and McLaughlin (1970); contains significantly more rubidium, manganese, and uranium than Bishop ash beds.
Pico7	Ventura, Calif.	NE1/4 NW1/4 sec. 27, T. 3 N., R. 21 W.; Santa Paula 7 1/2-minute	Volcanic ash about 6 mm thick in the Pico Formation of Pliocene and Pleistocene age west of South Mountain near Ventura, Calif.; locality description and chemical analysis of this ash reported by Sarna-Wojcicki and others (1980, p. 15, sample 27); named the South Mountain ash bed by Izett (1981, plate 1, bed no. 23).
79G96 79G97 79G98 79W96	Beaver, Utah	SW1/4 SW1/4 sec. 1, T. 29 S., R. 8 W.; Beaver 15-minute	Volcanic ash about 5 cm thick interbedded in Pliocene sediments exposed along Last Chance Bench near Beaver, Utah; separated stratigraphically from an underlying Huckleberry Ridge ash bed (formerly called Pearlette type B ash) of Izett and Wilcox (1982) by about 10 m of sediments.
Manix-1 79G72	San Bernardino, Calif.	NW1/4 SW1/4 sec. 11, T. N., R. 4 E.; Newberry 15-minute	Volcanic ash about 8 cm thick in sediments of Pleistocene Lake Manix; ash exposed in cliff along the south side of the Mojave River; chemical composition of the glass of this ash reported by Sarna-Wojcicki and others (1980, p. 46, sample 28); named the Manix-3 ash bed by Izett (1981, plate 1, bed no. 34).
Manix-4 79G35 79G71	San Bernardino, Calif.	NW1/4 SW1/4 sec. 11, T. N., R. 4 E.; Newberry 15-minute	Volcanic ash about 4 cm thick in sediments of ancient Lake Manix; exposed in cliff along the south side of the Mojave River; separated stratigraphically from an overlying ash bed (Manix-3 ash bed) by about 13 m of sediments, chemical composition of the glass of this ash reported by Sarna-Wojcicki and others (1980, p. 46, sample 30); named the Manix-2 ash bed by Izett (1981 plate 1, bed no. 35); separated stratigraphically by several meters of sediments from an underlying, thin volcanic ash correlated by Sarna-Wojcicki and others (1980, p. 39) with the Huckleberry Ridge ash of Izett and Wilcox (1982).
79G20 74W6	Mono, Calif.	NW1/4 SE1/4 sec. 5, T. 3 S., R. 32 E. White Mountain Peak 15-minute	Lapilli from air-fall pumice unit here assigned to the tuff of Taylor Canyon of Krauskopf and Bateman (1977); at pumice quarry north of Yellowjacket Canyon; youngest of three superposed air-fall pumice units; no downwind ash bed correlatives of this tephra identified yet; much less iron and more manganese, rubidium, and uranium in glass of pumice than glass of the basal air-fall unit of the Bishop Tuff; less iron in glass of pumice of the Glass Mountain-D and Glass Mountain-G ash beds; here called the Taylor Canyon-U ash bed.
79G29	Inyo, Calif.	NE1/4 NE1/4 sec. 14, T. 9 S., R. 34 E.; Waucoba Mtn. 15-minute quadrangle	In Pliocene sediments exposed in excavations adjacent to Waucoba Road; uppermost of three ash or lapilli beds; suspected source-area tephra is the middle of three air-fall pumice units in the Cowan pumice mine area described below; named the Taylor Canyon-C ash bed by Izett (1981, plate 1, bed no. 37).
79G25	Inyo, Calif.	NW1/4 sec. 2, T. 9 S., R. 34 E.; Waucoba Mtn. 15-minute quadrangle	In Pliocene sediments exposed along an east-trending gully; lowest of three ash or lapilli beds exposed at this locality; suspected source-area tephra is the middle of three air-fall pumice units in the Cowan pumice mine area described below; named the Taylor Canyon-C ash bed by Izett (1981, plate 1, bed no. 38).
79G10 74W60	Mono, Calif.	NW1/4 NE1/4 sec. 23, T. 2 S., R. 31 E.; Glass Mountain 15-minute	Lapilli from a pit excavated in pumice at the Cowan pumice mine; middle of three air-fall pumice units in mine area; sanidine separated from pumice lapilli dated by the K-Ar method at 2.10±0.02 m.y.; glass compostion of the pumice nearly identical to the glass composition of pumice of the uppermost of three air-fall pumice units at Yellowjacket Canyon; suspected source-area unit for the Taylor Canyon-C ash bed of Izett (1981).

74W5 79G18	Mono, Calif.	NW1/4 SE1/4 sec. 5, T. 3 S., R. 32 E. White Mountain Peak 15-minute	Lapilli from air-fall pumice unit here assigned to the tuff of Taylor Canyon of Krauskopf and Bateman (1977); at pumice quarry north of Yellowjacket Canyon; middle of three superposed air-fall pumice units; significantly less iron and more manganese, rubidium, and uranium in glass of pumice than glass of the basal air-fall unit of the Bishop Tuff; less iron in glass of pumice of the Glass Mountain-D and Glass Mountain-G ash beds; suspected source area unit for the Taylor Canyon-C ash beds of Izett (1981).
74W80	Mono, Calif.	NE1/4 NW1/4 sec. 17, T. 3 S., R. 32 E. White Mountain Peak 15-minute	Lapilli from air-fall pumice unit here assigned to the tuff of Taylor Canyon of Krauskopf and Bateman (1977); at pumice quarry about 2 km south of Yellowjacket Canyon; significantly less iron and more manganese, rubidium, and uranium in glass of pumice than glass of the basal air-fall unit of the Bishop Tuff; less iron in glass than in glass of the Glass Mountain-D and Glass Mountain-G ash beds; suspected source-area unit for the Taylor Canyon-C ash bed of Izett (1981).
78G167 78G174 79W98 79W99	Beaver, Utah	SW1/4 sec. 31, T. 28 S., R. 7 W.; SE1/4 sec. 14, T. 28 S., R. 8 W.; SE1/4 sec. 19, T. 28 S., R. 7 W.; and SE1/4 sec. 26, T. 28 S., R. 8 W.; Beaver 15-minute	Volcanic ash about 6 cm thick interbedded in Pliocene and Pleistocene sediments near Beaver, Utah; separated stratigraphically from an overlying Huckleberry Ridge ash bed of Izett and Wilcox (1982) by about 30 m of sediments; suspected source-area tephra is the middle of three air-fall tephra units in the Cowan pumice mine area described above.
79G17	Mono, Calif.	NW1/4 SE1/4 sec. 5, T. 3 S., R. 32 E. White Mtn. Peak 15-minute	Lapilli from air-fall pumice unit here assigned to the tuff of Taylor Canyon of Krauskopf and Bateman (1977); at pumice quarry north of Yellowjacket Canyon; lowest of three superposed air-fall pumice units exposed at this locality; significantly less iron and more manganese, rubidium, and uranium in glass of pumice than the basal air-fall unit of the Bishop Tuff; less iron in glass than in the glass of the Glass Mountain-D and Glass Mountain-G ash beds; suspected source-area unit for the Taylor Canyon-P ash bed of Izett (1981, plate 1, bed no. 38).
73W59	Inyo, Calif.	Sec. 4, T. 8., R. 34 E.; Bishop 15-minute	Volcanic ash bed in Pliocene sediments at Black Canyon southeast of Bishop, Calif.; uppermost of six ash or lapilli pumice beds separated by sediments; suspected source-area tephra is the lowest of three air-fall pumice units in the Cowan pumice mine area south of Benton Hot Springs, Calif.; here correlated with the Taylor Canyon-P ash beds of Izett (1981).
79G11	Mono, Calif.	NW1/4 NE1/4 sec. 23, T. 2 S., R. 31 E.; Glass Mountain 15-minute	Lapilli from a pit excavated in pumice; here assigned to the Tuff of Taylor Canyon of Krauskopf and Bateman (1977); lowest of three air-fall pumice units in the Cowan pumice mine area.
TSV20679	Nye, Nev.	Sec. 4, T. 17 S., R. 51 E.; Specter Range 15-minute	10-cm-thick ash in Pliocene sediments in Amargosa Valley; in south wall of southwesternmost sepiolite pit (W. J. Carr, written commun., 1982).
79G28 71W76	Inyo, Calif.	NE1/4 NE1/4 sec. 14, T. 9 S., R. 34 E.; Waucoba Mtn. 15-minute quadrangle	In Pliocene sediments exposed in excavations adjacent to Waucoba Road; middle of three ash and lapilli beds.
71W77	Inyo, Calif.	NE1/4 NE1/4 sec. 2, T. 9 S., R. 34 E.; Waucoba Mtn. 15-minute quadrangle	In Pliocene sediments exposed in excavations adjacent to Waucoba Road; lowermost of three ash or lapilli beds.
73W60	Inyo, Calif.	Sec. 4, T. 8., R. 34 E.; Bishop 15-minute	Volcanic ash bed in Pliocene sediments at Black Canyon southeast of Bishop, Calif.; second ash from the top of the ash bed sequence; named the Black Canyon-5 ash bed by Izett (1981, plate 1, bed no. 50).
UE5N	Nye, Nev.	Frenchman Flat, Nevada Test Site	In Pliocene sediments at 195 m depth in drill hole UE5N; named the Frenchman Flat ash bed by Izett (1981, plate 1, bed no. 47).

KM3A	San Bernardino, Calif.	Corner of secs. 22, 23, 26, and 27, T. 25 S., R. 43 E.; Searles Lake 15-minute	In Pliocene sediments in a borehole in the Searles Lake area; chemical composition of glass reported by Sarna-Wojcicki and others (1980, p. 17, sample 49); here correlated with the Frenchman Flat ash bed.
SW979	Nye, Nev.	SE1/4 sec. 15, T. 14 S., R. 49 E.; Lathrop Wells 15-minute	In sediments overlain by mid-Pleistocene eolian sand (W. J. Carr, written commun., 1982); provisionally here correlated with the Frenchman Flat ash bed of table 3.
73W61 73W68 73W69	Inyo, Calif.	Sec. 4, T. 8 S., R. 34 E.; Bishop 15-minute	Volcanic ash bed in Pliocene sediments at Black Canyon southeast of Bishop, Calif.; third ash from top of ash bed sequence; named the Black Canyon-4 ash bed by Izett (1981, plate 1, bed no. 51).

Table 5.--Composition of titanomagnetite microphenocrysts separated from samples of the Bishop Tuff of eastern California

[Analyses in weight percent; compiled from electron microprobe data of Hildreth (1977); ± is one standard deviation of the mean; Usp, molecular percent ulvospinel]

Bishop Tuff ash-flow lobe of Hildreth (1977)	Number of samples	Al_2O_3	MnO	MgO	FeO	TiO_2	[1] Fe_2O_3	[2] FeO	[3] Usp
UPPER UNIT OF THE BISHOP TUFF (CLINOPYROXENE- AND ORTHOPYROXENE-BEARING PUMICE)									
Mono	6	1.3±0.04	0.47±0.03	0.7±0.06	84.1±0.68	9.2±0.10	25.9	50.6	38.6
Adobe Valley	10	1.2± .07	.55± .07	.6± .06	82.9± .80	9.3± .14	26.5	49.7	38.2
San Joaquin-2	2	1.1± .06	.75± .06	.5± .06	82.6±1.0	9.4± .04	26.8	49.4	38.2
Tableland	7	1.2± .09	.74± .10	.5± .08	84.0± .68	9.3± .26	26.4	50.4	38.6
Mean		1.2	0.63	0.6	83.4	9.3	25.4	50.0	38.4
LOWER UNIT OF THE BISHOP TUFF (NONPYROXENE BEARING PUMICE)									
Little Round Valley	4	1.0±0.03	0.97±0.14	0.3± .06	84.4±1.04	9.2±0.14	26.0	50.9	38.6
San Joaquin-1	4	.9± .06	.87± .03	.3± .01	84.3± .68	9.0± .10	25.6	51.0	38.5
Upper Owens Gorge	4	.9± .01	1.03± .06	.3± .01	83.7± .65	9.2± .24	26.1	50.4	38.3
Gorges	5	.9± .07	.97± .10	.2± .01	84.1± .65	9.2± .04	26.1	50.6	38.5
Chidago	8	1.0± .06	.83± .04	.3± .03	83.9± .76	9.1± .18	25.9	50.6	38.5
Basal ash-fall	8	.9± .04	.84± .01	.3± .01	84.4± .41	9.1± .09	25.7	50.9	38.6
Mean		0.9	0.94	0.3	84.0	9.1	25.9	50.7	38.5

[1] Weight percent Fe_2O_3 recalculated by the author using the method of Carmichael (1967)

[2] Weight percent FeO recalculated by the author using the method of Carmichael (1967)

[3] Molecular percent ulvospinel recalculated by the author using the method of Carmichael (1967)

Table 6.--Composition of titanomagnetite microphenocrysts of Bishop Tuff and Bishop ash beds as determined by the electron microprobe

[Elements in weight percent; analyses by G. A. Izett]

Loc. No. Fig. 1	Sample No.	Locality	MnO	Al_2O_3	MgO	FeO	TiO_2
		Bishop Tuff (air-fall pumice)					
1	64W96	Insulating Aggregate Quarry, 10 km north of Bishop, Calif.	0.83	1.04	0.36	84.9	9.2
6	79G23	Toms Place, Calif.	.89	1.02	.32	85.0	9.2
4	64W109	Benton Hot Springs, Calif.	.88	1.02	.35	85.9	9.2
		Bishop ash beds					
8	68W156	Shoshone quadrangle, Calif.	0.84	0.98	0.32	84.9	9.0
22	65W1	Paradox, Colo.	.83	.89	.33	88.4	9.2
26	78W17	Gay Mines, Idaho	.90	.98	.28	85.3	9.0
29	70W19	Clayton Valley, Nev.	.84	1.06	.30	85.8	9.2
30	78G203	Jackass Flats, Nev.	.92	.94	.30	82.3	8.7
31	79G4	Striped Hills, Nev.	.90	1.00	.30	85.4	9.2
31	79W61	Skeleton Hills, Nev.	.89	.98	.30	83.0	9.0
34	73W101	Grama Siding, N. Mex.	.83	.89	.27	87.5	9.2
38	78G197	Polar Mesa quadrangle, Utah	.87	.98	.33	85.8	9.2
41	79G159	Cove Fort, Utah	.87	1.02	.35	83.0	9.0
39	79G39	Delta, Utah	.87	1.02	.33	82.9	9.0
46	74G20	Laramie, Wyo.	.84	1.02	.30	84.4	8.8

Table 8.--Potassium-argon analytical data used for isochron plot of figure 4

[Laboratory numbers are those of table 7; CV, coefficient of variation; leaders (---) indicate coefficient of variation not calculated]

Lab No.	Analyzed material	$^{40}Ar/^{36}Ar$	CV	$^{40}K/^{36}Ar$ X10^4	CV
	UPPER PART OF BISHOP TUFF (PYROXENE-BEARING PUMICE)				
DKA3865	Sanidine	869.6	1.11	1390.4	1.73
DAK3953	Sanidine	730.0	1.24	984.8	1.43
DKA3954	Sanidine	592.4	1.25	687.8	1.44
DKA3941	Biotite	298.2	1.04	10.8	1.62
DKA3866	Biotite	301.2	1.13	8.5	2.19
DKA3876	Plagioclase	330.3	0.87	79.4	1.66
DKA4130	Plagioclase	309.7	1.11	28.1	1.17
DKA3867	Glass	302.9	0.87	12.7	1.67
	LOWER PART OF BISHOP TUFF (NONPYROXENE-BEARING PUMICE)				
DKA3877	Sanidine	1077.8	0.80	1820.9	1.62
DKA3955	Sanidine	645.6	1.25	801.6	1.82
DKA4116	Sanidine	541.7	---	570.9	---
DKA4117	Sanidine	479.1	---	440.5	---
DKA4124	Sanidine	627.6	---	758.4	---
DKA4125	Sanidine	496.1	---	469.9	---
DKA3957	Biotite	302.3	1.24	9.5	1.81
DKA4122	Plagioclase	317.7	---	56.3	---
DKA3958	Plagioclase	334.1	1.25	48.1	1.82

Table 9.--Potassium-argon ages of pumice cobbles from a conglomerate unit of the Friant Pumice Member of the Turlock Lake Formation at the California Industrial Minerals mine near Friant, Calif.

[K-Ar ages determined by G. A. Izett, J. D. Obradovich, and H. H. Mehnert; ages calculated using the decay constants and isotope abundances recommended by Steiger and Jager (1977); ± is one sigma; potassium determined by flame photometry by V. Merrit except for sample DKA3937 which was determined by the isotope dilution method by J. D. Obradovich]

Lab No.	Potassium (percent)	Sample (weight) (gm)	Radiogenic ^{40}Ar/gm x10^{-11} mole	Radiogenic ^{40}Ar (percent)	Age x10^6 years	Sample No. and dated material	Sample location and remarks
DKA3958	9.00	3.9908	1.6563	61.7	1.06±0.02	80G20S, sanidine.	Pumice cobbles from near the base of conglomerate unit at the California Industrial Minerals Mine near Friant, Calif.
DKA3937	9.097	4.8105	2.8121	88.5	1.78±0.03	79G73, sanidine.	Do.
DKA4132	9.13	0.9713	0.3028	2.4	0.19±0.04	79G73A, sanidine	Do.

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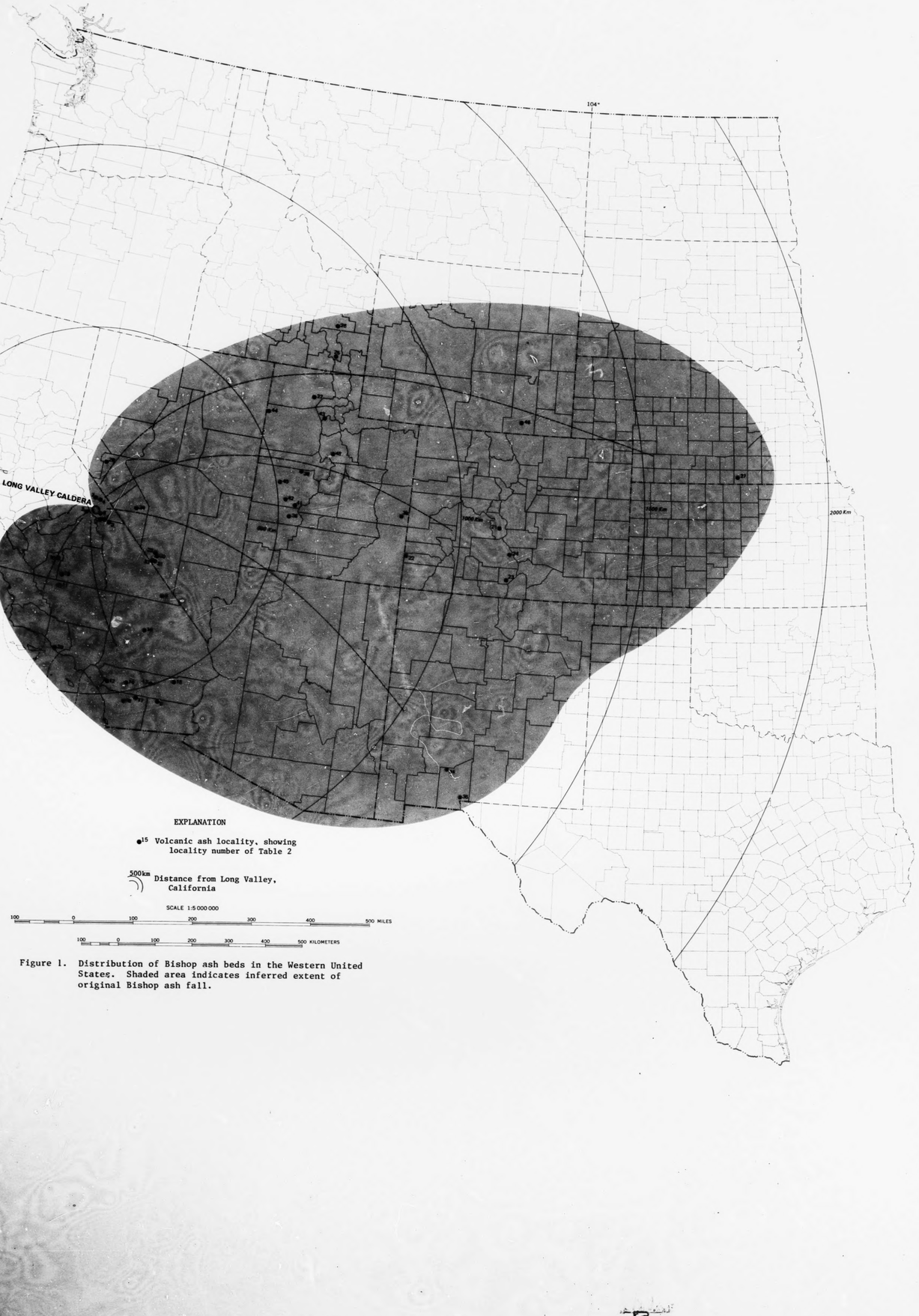

Figure 1. Distribution of Bishop ash beds in the Western United States. Shaded area indicates inferred extent of original Bishop ash fall.

Table 1. Chemical analyses of the glass phases of some Bishop ash beds and Bishop Tuff tephra from the Western United States

[Localities plotted on figure 1 and described in table 2; analyses for all elements except Ca determined by the instrumental neutron activation method; Ca determined by atomic absorption photospectrometric method; amounts of elements in parts per million except Fe and Ca which are in weight percent; analyses of samples with laboratory numbers starting with (Xw letter D made by R. T. Millard, D. M. McKown, and R. J. Knight; analyses of samples with laboratory numbers composed only of numerals 730 made by G. A. Borchardt; other chemical analyses reported by Sarna-Wojcicki and others (1980); leaders (---) indicate no data; samples having identical field numbers and locality name, but different laboratory numbers, are splits of the same master sample but analyzed during different analytical runs; samples with the same locality name, but different field numbers, are from the same ash bed but at slightly different positions in the ash bed; LP, sample from lower part of bed; MP, sample from middle part of bed; UP, sample from upper part of bed]

Fig. 1 Loc. No.	Lab. No.	Field No.	Locality and sampled material	Cs	Rb	Ba	Sr	Th	U	La	Ce	Nd	Sm	Eu	Gd	Tb	Dy	Tm	Yb	Lu	Ta	Zr	Hf	Sb	Sc	Mn	Fe	Ca
			BISHOP TUFF (from basal 4-m-thick air-fall unit analyzed by similar analytical methods)																								
1	D216903	79G14	IAQ 1/, Calif.; MP; locality A; pumice lapilli	4.5	150	55	143	17.7	7.7	15.4	29.8	14	3.5	0.05	2.5	0.49	3.5	---	2.2	0.32	2.4	122	3.0	0.9	2.6	227	0.46	0.29
1	D228477	79G75	IAQ, Calif.; LP; locality B; pumice lapilli	5.4	184	38	---	19.6	7.6	16.4	36.1	17	3.9	.03	---	.70	3.6	---	2.6	.39	2.5	123	3.1	1.0	2.8	268	.47	---
1	D228478	79G77	IAQ, Calif.; MP; locality B; pumice lapilli	5.4	165	32	---	19.9	7.9	16.8	39.2	19	3.9	.04	4.8	.67	3.7	.32	2.7	.40	2.5	126	3.2	1.0	2.8	261	.48	---
1	D228479	79G78	IAQ, Calif.; UP; locality B; pumice lapilli	5.4	168	39	---	20.4	8.1	18.3	43.8	20	4.4	.04	4.8	.66	3.9	.33	2.8	.44	2.7	126	3.3	1.1	2.9	263	.54	---
1	D228482	79G81	IAQ, Calif.; LP; locality C; pumice lapilli	5.4	161	39	---	19.6	7.8	16.2	35.1	17	3.7	.02	4.4	.56	4.1	.34	2.6	.39	2.5	120	3.0	1.0	2.7	267	.49	---
1	D228483	79G82	IAQ, Calif.; MP; locality C; pumice lapilli	5.4	157	40	---	19.3	7.5	17.6	35.1	17	3.8	.03	4.0	.58	4.2	---	2.5	.33	2.4	123	3.0	1.0	2.7	263	.49	---
2	D216905	79C21	Owens River, Calif.; MP; pumice lapilli	5.3	163	42	---	19.9	7.2	16.5	32.9	16	3.9	.03	4.2	.58	3.4	---	2.6	.38	2.5	---	3.2	1.0	2.7	294	.51	.30
3	D226486	79G85	Pumice quarry, northeast of Lawe, Calif.; MP	5.4	154	41	---	18.7	7.7	16.8	34.3	17	3.8	.04	---	.55	3.8	---	2.6	.35	2.3	105	2.8	1.0	2.7	245	.48	---
			Mean 2/	5.3	160	43	---	19.4	7.7	16.8	36.2	17	3.9	0.04	4.1	0.60	3.8	0.33	2.6	0.38	2.5	120	3.1	1.0	2.8	256	0.48	.30
			± One standard deviation of mean	0.3	6	10	---	0.8	0.3	0.9	4.4	2	0.3	0.01	0.9	0.07	0.3	0.01	0.2	0.04	0.1	7	0.2	0.05	0.1	14	0.03	---
1	20	64W96	IAQ, Calif.; MP; locality D; pumice lapilli	6.5	163	54	---	19.6	7.0	18.4	35.0	15	4.4	.04	---	.34	4.2	---	1.8	.48	2.2	57	3.6	1.1	2.6	257	.51	---
1	730	64W96	IAQ, Calif.; MP; locality D; pumice lapilli	---	180	67	---	19.9	6.5	17.5	36.9	19	4.4	---	---	---	4.0	---	2.6	.52	2.5	---	4.1	---	2.8	266	.53	.30
1	NASW115	85-8	IAQ, Calif.; 1 m below top of bed; pumice lapilli	6.0	187	---	---	21.0	6.5	19.4	47.1	20	3.7	.04	---	---	4.2	---	2.4	.56	4.1	---	2.7	.37	3.2	---	3.7	---	.31
2	922K	B-93	Owens River, Calif.; pumice lapilli 3/	6.1	200	---	---	21.4	7.1	18.5	42.2	20	3.9	.01	---	.60	4.2	---	2.8	.37	2.2	---	3.9	---	2.9	281	.55	---
5	NASW3	J-328	Devils Post Pile quadrangle, Calif.; pumice lapilli 3/	6.1	185	---	---	21.4	7.2	18.3	42.1	18	3.8	.03	---	.63	4.0	---	2.9	.41	2.2	---	4.0	---	3.2	274	.50	.29
6	578	69W140	Roadcut near Toms Place, Calif.; MP; pumice lapilli	6.9	183	52	---	19.5	7.3	17.3	38.6	19	4.2	.06	---	---	4.2	---	2.5	.53	2.8	207	3.8	---	2.7	271	.51	.28
			BISHOP TUFF (from surge deposit overlying basal air-fall unit)																								
1	D226484	79G83	IAQ, Calif.; surge deposit; MP; locality C; pumice lapilli	5.0	153	39	---	18.7	7.1	18.7	37.8	18	3.7	0.04	---	0.55	3.8	---	2.5	0.38	2.3	96	2.9	1.0	2.6	261	0.48	---
1	D229088	80G23	IAQ, Calif.; surge deposit; MP; locality E; pumice lapilli	5.7	162	---	---	19.7	7.0	19.7	36.1	16	3.8	.04	3.5	.55	3.5	---	2.3	.34	2.3	63	3.1	0.9	2.6	241	.48	---
			BISHOP TUFF (from lowest ashflows of the lower part; nonpyroxene bearing pumice)																								
1	D216904	79G15	IAQ, Calif.; thick ash-flow unit; pumice lapilli	4.6	150	---	---	18.2	8.2	22.8	45.6	17	3.9	0.04	3.6	0.52	3.0	---	2.3	0.34	2.2	124	3.1	0.9	2.5	241	0.50	0.31
1	D229087	80G21	IAQ, Calif.; lowest lenticular ash-flow; pumice lapilli	5.9	163	8	---	19.8	8.1	18.9	26.8	14	4.0	.03	---	.57	4.0	---	2.6	.37	2.5	---	3.1	1.0	2.8	265	.46	---
1	D226480	79G79A	IAQ, Calif.; thick ash flow unit; pumice lapilli	5.3	174	37	23	19.1	7.4	18.7	40.7	20	3.9	.04	4.2	.63	3.4	0.31	2.6	.39	2.6	113	3.1	1.0	2.7	263	.52	---
1	D225485	79G84	IAQ, Calif.; thick ash flow unit; pumice lapilli	5.0	144	39	96	17.8	6.6	21.5	39.3	18	3.7	.04	3.4	.50	3.6	---	2.3	.35	2.2	120	2.8	.9	2.5	250	.50	---
1	D225486	79G86	IAQ, Calif.; 4 m above 79G84; pumice lapilli	5.5	168	36	---	20.1	8.0	17.0	40.8	18	4.1	.03	4.3	.69	3.4	.33	2.7	.40	2.6	128	3.2	1.0	2.8	295	.54	---
3	D226487	79G86	Pumice quarry, northeast of Lawe, Calif.; LP, pumice lapilli	5.3	150	124	46	18.2	6.9	18.7	36.5	14	3.6	.10	3.8	.55	3.9	.24	2.4	.34	2.2	113	2.8	.9	2.9	295	.64 4/	---
			BISHOP TUFF (from lowermost ashflow of the upper part; pyroxene-bearing pumice)																								
7	D226489	79G88	Taylor Canyon, Calif.; lower part; pumice blocks	2.5	90	237	---	12.3	2.8	30.6	79.5	23	3.1	0.19	2.4	0.30	1.9	0.16	1.1	0.18	1.1	105	2.8	0.5	1.4	118	0.35	---
7	D226492	79G94	Cowtrack Mountain quadrangle, Calif.; pumice block	2.5	92	300	43	12.4	3.4	31.8	82.0	26	3.2	.22	2.7	.28	2.1	---	1.1	.18	1.1	110	3.0	.5	1.5	141	.41	---
			BISHOP ASH BEDS																								
8	7	68W156	Shoshone quadrangle, Calif. 3/	6.9	169	51	---	19.0	7.1	16.8	34.0	20	4.0	0.03	---	0.44	4.1	---	1.4	0.49	2.1	76	3.6	1.1	2.6	249	0.46	0.31
8	NASW183	Teco-5	Shoshone quadrangle, Calif. 3/	5.9	185	---	---	21.0	7.4	18.7	42.9	17	3.6	.04	---	.58	4.0	---	2.7	.36	2.1	---	3.8	---	3.0	254	.50	---
9	NASW71	Salton-5	Durmid 7 1/2-minute quadrangle, Calif. 3/	5.6	185	---	---	20.2	6.7	20.2	44.2	17	3.6	.04	---	.58	3.9	---	2.6	.35	2.1	---	3.7	---	2.9	266	.48	---
9	NASW116	Salton-1	Durmid 7 1/2-minute quadrangle, Calif. 3/	6.1	195	---	---	21.9	7.2	17.7	42.6	19	3.7	.03	---	.61	4.3	---	2.8	.39	2.2	---	3.8	---	3.2	272	.50	---
9	NASW63	Salton-2	Durmid 7 1/2-minute quadrangle, Calif. 3/	5.3	170	---	18	19.8	6.8	17.2	37.5	18	3.5	.06	---	.52	3.5	---	2.3	.33	1.9	---	3.5	---	3.0	252	.49	---
9	NASW117	Salton-2A	Durmid 7 1/2-minute quadrangle, Calif. 3/	5.6	178	---	---	20.1	6.5	21.6	48.6	18	3.6	.04	---	.55	3.7	---	2.5	.31	2.0	---	3.5	---	3.0	252	.52	---
10	576		San Joaquin Valley, Calif. 3/	5.3	155	84	---	16.4	6.1	15.2	34.8	21	4.0	.08	---	.59	4.1	---	2.1	.45	2.4	132	3.2	1.4	---	230	.53	.33
12	NASW75	ELSI-1	Murietta 7 1/2-minute quadrangle, Calif. 3/	5.6	181	---	---	19.8	6.5	20.3	46.6	18	3.6	.03	---	.57	3.7	---	2.6	.34	2.0	---	3.6	---	2.8	262	.50	---
14	NASW124	87-87-1	Idylwild 15-minute quadrangle, Calif. 3/	5.6	188	---	---	20.6	6.7	20.0	44.8	20	3.6	.03	---	.51	3.9	---	2.4	.37	2.1	---	3.6	---	3.0	266	.51	---
19	NASW4	2325168	Alpaugh 7 1/2-minute quadrangle, Calif. 3/	5.3	169	---	---	19.0	6.1	25.0	52.2	17	3.6	.05	---	.52	3.5	---	2.4	.31	1.9	---	3.6	---	2.9	252	.54	---
21	27	67W131	Centerville, Colo.; middle part of thin impure ash	5.5	130	---	---	18.1	6.2	24.8	60.4	21	3.9	.07	---	.61	3.9	---	1.8	.42	1.8	74	3.8	1.0	2.4	241	.53	.33
22	528	65W1	Paradox, Colo.; lower part	4.8	154	82	---	16.6	6.3	23.3	45.5	21	3.9	.07	---	.51	3.9	---	1.8	.46	2.1	96	3.7	.8	2.4	265	.54	.34
23	D229098	80W90	Alamosa, Colo. 3/	5.4	130	127	36	15.7	5.9	24.6	47.1	17	3.6	.08	3.2	.46	3.6	---	1.9	.29	1.9	---	2.7	.8	2.2	229	.47	.34
26	D234834	80W92	San Luis Valley, Colo.; middle part of thin impure ash	4.6	137	78	13	16.1	5.6	25.9	54.4	18	3.6	.08	---	.53	3.6	---	2.0	.29	2.0	83	3.1	1.0	2.8	261	.48	.30
25	D216900	78W217	Red Rock Pass, Idaho 3/	4.5	168	60	---	18.1	7.3	20.9	38.5	16	3.7	.05	2.8	.51	2.9	---	2.4	.40	2.3	119	2.9	.9	2.6	248	.48	.31
25	D216902	78W218	Red Rock Pass, Idaho 3/	5.1	156	---	---	19.4	7.8	16.9	33.9	16	3.6	.02	---	.57	3.3	---	2.4	.35	2.4	124	3.1	1.0	2.7	261	.46	---
26	D198718	78W17	Gay Mines, Idaho; lower 10 cm of a 50 cm thick bed	5.7	172	45	---	20.1	8.0	17.2	38.8	19	4.0	.03	4.7	.64	4.7	.39	2.6	.37	2.6	---	3.4	1.2	2.8	252	.46	---
27	D198716	71W9	Nuckolls Co., Nebr.; from middle of thick impure bed	5.4	141	117	16.5	6.3	26.7	53.2	21	3.5	.05	---	3.5	.49	3.6	---	2.0	.30	2.0	---	3.1	.9	2.2	218	.50	.38
27	5	64W8	Nuckolls Co., Nebr.; from middle of thick impure bed	5.3	151	102	---	15.9	5.7	27.1	50.7	25	4.4	.13	---	.57	3.0	---	2.0	.42	2.1	168	3.4	.9	2.2	230	.53	.33
27	505	64W8	Nuckolls Co., Nebr.; from middle of thick impure bed	4.8	152	105	16.5	5.9	27.1	51.6	21	3.5	.05	---	3.5	.51	3.6	---	2.2	.42	2.1	180	3.6	.9	2.3	253	.55	---
27	541	64W8	Nuckolls Co., Nebr.; from middle of thick impure bed	5.5	165	106	---	16.3	5.8	27.0	47.3	15	3.6	.10	---	.60	3.1	---	1.9	.39	1.7	75	3.2	.9	2.3	213	.54	---
27	D226494	64W8	Nuckolls Co., Nebr.; (coarse fraction; +120 -100 mesh); MP	4.3	132	112	16.2	5.8	30.3	54.4	24	3.5	.05	---	4.2	.58	4.0	---	2.4	.31	1.9	111	3.0	.9	2.4	215	.53	---
27	D226495	64W8	Nuckolls Co., Nebr.; (fine fraction; +200 -150 mesh); MP	4.4	131	86	---	16.4	5.9	27.4	47.9	19	3.5	.09	4.4	.45	3.1	.21	1.9	.29	1.9	115	2.8	.9	2.2	213	.50	---
29	585	70W21	Clayton Valley, Nev. 3/	6.5	181	63	---	17.4	6.6	18.5	44.4	21	4.0	.07	---	.70	5.3	---	2.1	.43	2.6	115	3.8	1.0	2.9	250	.49	.33
30	D216894	78C203	Jackass Flats, Nev. 3/	5.0	159	38	---	18.7	8.3	16.0	32.2	14	3.6	.02	3.8	.55	3.6	---	2.5	.37	2.4	124	3.0	1.0	2.6	253	.44	.30
31	D216893	79G61	Skeleton Hills, Nev. 3/	5.3	162	58	---	19.5	8.5	16.5	34.3	18	3.7	.03	---	.53	3.8	---	2.7	.34	2.5	138	3.1	1.0	2.8	261	.47	.30
31	D216896	79G4	Striped Hills, Nev.; lower part of 1-m-thick bed	5.1	163	55	---	19.4	8.1	15.8	33.3	14	3.7	.03	3.2	.58	3.6	.30	2.5	.39	2.6	129	3.1	1.1	2.7	250	.46	.30
32	D216942	79G18	Calico Hills, Nev. 3/	5.4	157	38	---	18.3	7.2	16.7	35.1	18	3.6	.03	3.8	.60	4.3	---	2.5	.41	2.2	124	2.9	1.0	2.7	236	.47	.29
33	D229069	80W71	Big Dune quadrangle, Nev. 3/	5.7	163	36	---	19.3	7.8	15.7	33.8	17	3.9	.04	4.1	.60	3.6	.38	2.4	.36	2.5	---	3.1	.9	2.7	256	.48	.36
33	D229070	80W70	Big Dune quadrangle, Nev. 3/	5.6	160	32	---	19.3	7.4	18.4	38.4	17	3.6	.04	4.0	.60	3.6	.34	2.4	.38	2.4	---	3.2	.9	2.6	254	.48	.32
34	D198713	73W101	Grama, N. Mex.; all samples from middle of 30-cm-thick bed	4.6	151	74	---	16.9	6.3	27.1	56.3	20	3.6	.07	4.6	.49	3.5	.32	2.0	.32	2.1	---	3.1	.9	2.3	212	.50	.42
34	D226497	73W101	Grama, N. Mex.; (coarse fraction; +120 -100 mesh)	4.0	128	93	16	15.5	5.5	29.4	57.1	21	3.5	.09	---	.51	3.6	---	2.2	.29	2.2	74	3.1	.9	2.2	209	.51	---
34	D226498	73W101	Grama, N. Mex.; (fine fraction; +200 -150 mesh)	4.5	140	76	---	16.1	5.5	27.7	52.9	18	3.5	.09	---	.56	3.3	---	2.0	.32	1.9	108	2.9	.8	2.2	219	.51	---
35	D198712	79W156	Franklin Mountains, N. Mex.; from middle of 5-cm-thick bed	3.9	127	110	33	13.7	4.6	25.1	50.8	19	3.1	.08	---	.44	3.1	.19	1.8	.28	---	---	2.5	.7	1.9	186	.43	.31
35	723	79W156	Franklin Mountains, N. Mex.; from middle of 5-cm-thick bed	3.0	148	162	---	15.4	7.0	26.6	49.0	22	4.2	---	---	---	3.5	---	2.1	.39	1.9	---	3.4	---	2.1	202	.52	.31
36	D198708	73G61	Mineral Mountains, Utah; upper part of 2-m-thick bed	4.9	159	71	---	19.4	8.0	23.4	49.0	19	4.1	.03	---	.52	3.9	.40	2.5	.32	2.4	---	3.2	1.0	2.7	253	.50	.38
36	D234833	80G15	Mineral Mountains, Utah; basal 5-10 cm of 2-m-thick bed	5.9	162	---	~86	19.6	7.6	19.4	32.8	16	3.5	.03	---	.59	3.8	.41	2.5	.37	2.5	68	3.1	1.0	2.7	261	.47	.30
38	19	65W5	Polar Mesa quadrangle, Utah; lowest 6 cm of 1-m-thick bed	5.4	153	68	---	17.9	6.9	18.0	31.3	18	3.9	.03	---	.57	3.7	---	1.5	.45	2.0	88	3.3	1.0	2.4	244	.44	.30
38	NASW149	65W5	Polar Mesa quadrangle, Utah; lowest 6 cm of 1-m-thick bed	4.7	202	---	---	21.9	7.2	19.1	43.4	21	4.2	.05	---	.65	4.2	---	2.4	.42	2.3	---	3.7	---	2.8	279	.51	---
39	D216895	79C39	Delta, Utah; lower part of 25-cm-thick ash bed	4.9	156	---	---	18.4	7.9	15.5	31.6	15	3.5	.03	---	.54	3.5	.27	2.4	.37	2.3	---	2.9	1.0	2.6	244	.44	.31
40	D216901	79W86	Sevier Lake, Utah 3/	5.9	161	---	---	19.4	8.4	22.8	51.6	19	3.5	.05	---	.58	4.0	.48	2.6	---	2.6	---	3.5	1.1	2.8	273	.49	.30
40	D229085	80W84	Sevier Lake, Utah 3/	4.2	132	---	---	15.6	6.4	22.0	44.8	19	4.1	.05	2.7	.48	3.5	---	1.8	.26	2.0	107	2.9	1.0	2.5	266	.47	---
40	D234856	80W84	Sevier Lake, Utah 3/	4.0	130	---	---	15.5	5.7	21.4	42.9	18	3.4	.04	3.0	.47	2.9	---	1.8	.26	1.9	---	2.9	.7	2.5	246	.47	---
41	D198709	73W58	Cove Fort, Utah; MP	5.5	170	---	128	19.5	8.6	16.3	35.1	15	3.4	.02	---	.60	4.6	.52	2.9	.37	2.5	---	3.2	1.1	2.7	276	.45	---
42	D225437	79W101	Black Rock, Utah; 3/	6.5	191	39	---	18.5	7.2	15.4	33.3	15	3.6	.03	---	.58	3.5	---	2.3	.36	2.3	119	2.9	1.0	2.6	260	.47	---
43	28	57P133	Saltair, Utah	6.0	147	49	---	17.0	6.5	22.4	38.9	21	4.0	---	---	.60	3.5	---	1.5	.40	1.9	81	3.3	.9	2.3	244	.52	.36
44	29	8-66	Wendover, Utah 3/	6.5	162	51	---	18.8	8.8	17.7	33.0	16	4.0	.06	---	.58	3.2	---	1.6	.45	2.1	91	3.4	1.1	2.4	239	.46	.31
45	D226497	67W161	Payson, Utah; lower 14 cm of 2.5-m-thick bed	6.5	161	105	---	18.5	6.3	21.4	40.7	20	3.9	.04	---	.61	3.2	---	1.5	.45	2.1	95	3.7	1.1	2.5	244	.52	.31
45	D226496	67W161	Payson, Utah; lower 14 cm of 2.5-m-thick bed	5.3	149	58	---	18.2	6.9	19.9	36.6	17	3.8	.05	---	.55	3.6	---	2.2	.32	2.2	107	2.9	1.0	2.5	266	.47	---
45	D229086	80C18	Payson, Utah; lower 10 cm of 1-m-thick bed	.8	159	---	---	19.4	7.6	15.8	32.9	14	3.8	.02	3.9	.58	3.7	.30	2.5	.35	2.4	112	3.1	1.0	2.7	258	.46	---
46	D198710	74G24	Laramie, Wyo.; lowest 6 cm of 25-cm-thick bed	5.2	156	32	---	18.4	7.2	19.6	44.1	18	3.5	.04	3.4	.57	4.1	.39	2.3	.33	2.4	---	3.2	1.2	2.5	230	.47	.30

1/ IAQ, Insulating Aggregates pumice quarry north of Bishop, Calif., now abandoned
2/ Mean of only those samples analyzed by R. T. Millard, D. M. McKown, and R. J. Knight at the U.S. Geological Survey laboratory in Denver, Colo.
3/ Not known by me where sample was collected stratigraphically within the ash bed
4/ Here questionably included with the Bishop Tuff; the iron and manganese contents are anomlously high compared to other Bishop Tuff samples
5/ From 2-m-thick bed in the Norrego Formation in the Salton Trough; this sample referred to as the Insulating Aggregate Quarry type of Bishop ash by Sarna-Wojcicki and others (1980)
6/ From 2-m-thick bed in the Norrego Formation in the Salton Trough; this sample referred to as the Owens River Gorge type of Bishop ash by Sarna-Wojcicki and others (1980)
7/ From 2-m-thick bed in the Norrego Formation in the Salton Trough; this sample referred to as the Priest Pumice mine type of Bishop ash by Sarna-Wojcicki and others (1980)

Table 3.--Chemical analyses of the glass phases of some Pliocene and Pleistocene rhyolite tephra units compositionally and mineralogically similar to the Bishop Tuff and ash beds in the Long Valley-Glass Mountain area, Calif., and some ash beds in California, Nevada, and Utah suspected to be their correlatives

[Locality descriptions given in table 4; analyses for all elements done by the instrumental neutron activation method except for Ca which was made by atomic absorption methods; analysts for samples beginning with the letter D was H. T. Millard, D. M. McKown, and R. J. Knight; analyst for samples with laboratory numbers composed only of numerals was G. A. Borchardt; other chemical analyses reported by Sarna-Wojcicki and others (1980); leaders (---) indicate no data; samples with identical field numbers but different laboratory numbers were analyzed during different analytical runs; some ash bed names are those used by Izett (1981) except for newly named ash beds of this report; amounts of elements in parts per million except Fe and Ca which are listed in weight percent]

Lab. No.	Sample No.	Locality and sampled material	Cs	Rb	Ba	Sr	Th	U	La	Ce	Nd	Sm	Eu	Gd	Tb	Dy	Tm	Yb	Lu	Ta	Zr	Hf	Sb	Sc	Mn	Fe	Ca
		FRIANT MINE CONGLOMERATE UNIT																									
D226475	79G73A	Friant, Calif.; pumice cobbles	4.6	147	88	---	17.8	6.7	24.3	50.5	21	3.6	0.07	3.9	0.56	3.2	0.28	2.3	0.34	2.2	119	3.0	0.9	2.5	224	0.47	---
NASW2	63c126	Friant, Calif.; pumice cobbles	5.4	171	---	---	19.4	6.1	24.1	50.8	20	3.6	.04	---	.53	3.4	---	2.4	.30	1.9	---	3.6	---	2.8	252	.52	---
		MILLERTON LAKE ASH BED (AGE UNCERTAIN)																									
D226476	79G74	Friant, Calif.; 3-m-thick ash bed	4.7	151	50	---	17.9	6.8	21.7	46.5	18	3.6	0.05	4.3	0.58	3.4	0.28	2.4	0.34	2.2	120	3.0	0.9	2.5	234	.40	---
D158717	70W1	Friant, Calif.; 3-m-thick ash bed	5.0	159	73	---	18.3	6.8	23.6	51.5	18	3.7	.06	---	.55	3.5	---	2.3	.28	2.3	131	3.2	1.0	2.5	223	.38	0.29
		GLASS MOUNTAIN-D ASH BED (ABOUT 1.0 M.Y.)																									
D226905	79G12	Glass Mountain quadrangle, Calif.; pumice blocks	5.0	166	86	95	18.8	7.6	17.7	35.0	19	4.0	0.05	---	0.56	3.8	---	2.6	0.37	2.5	117	3.0	0.9	2.9	274	.53	.35
D226488	79G87	White Mountain Peak quadrangle, Calif.; pumice lapilli	5.3	159	81	---	19.8	7.6	19.3	39.8	19	4.1	.05	3.4	.56	3.6	---	2.6	.40	2.5	111	3.1	1.0	3.0	287	.61	---
D198714	73W62	Bishop quadrangle, Calif.; volcanic ash below Bishop Tuff	4.8	154	56	---	17.2	6.7	22.7	51.0	19	4.1	.03	3.8	.57	4.5	---	2.4	.37	2.3	134	3.1	1.0	2.5	246	.49	.34
D216898	68W155	Lake Tecopa, Calif.; volcanic ash	5.

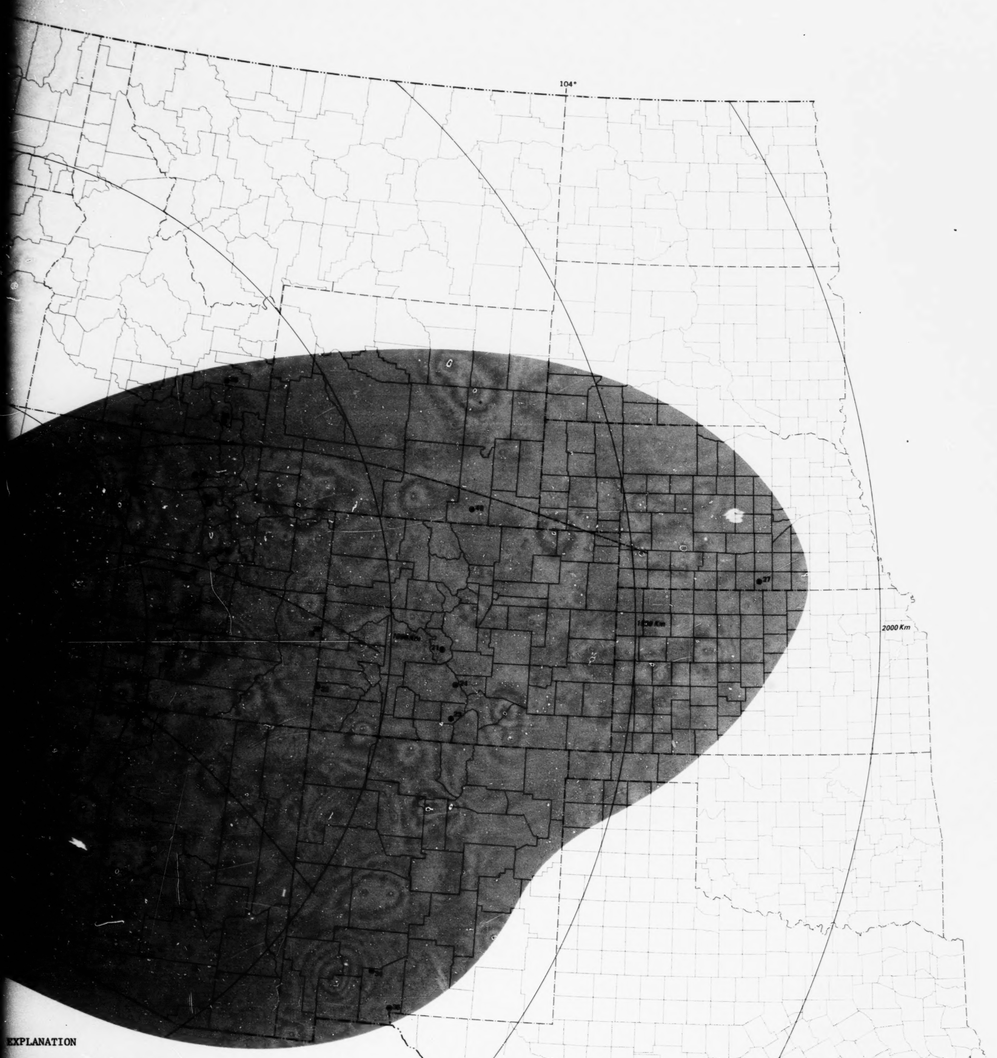

Table ___ Chemical analyses of the glass phases of some Bishop ash beds and Bishop Tuff tephra from the Western United States

Localities plotted on figure 1 and described in table 2; analyses for all elements except Ca determined by the instrumental neutron activation method; Ca determined by atomic absorption photospectrometric method; amounts of elements in parts per million except Fe and Ca which are in weight percent; analyses of samples with laboratory numbers starting with the letter D made by H. T. Millard, D. M. McKown, and R. J. Knight; analyses of samples with laboratory numbers composed only of numerals 730 made by G. A. Borchardt; other chemical analyses reported by Sarna-Wojcicki and others (1980). Leaders (---) indicate no data; samples having identical field numbers and locality name, but different laboratory numbers, are splits of the same master sample but analyzed during different analytical runs; samples with the same locality name, but different field numbers, are from the same ash bed but at slightly different positions in the ash bed; LP, sample from lower part of bed; UP, sample from upper part of bed]

Fig. 1 Loc. No.	Lab. No.	Field No.	Locality and sampled material	Ca	Rb	Ba	Sr	Th	U	La	Ce	Nd	Sm	Eu	Gd	Tb	Dy	Tm	Yb	Lu	Ta	Zr	Hf	Sb	Sc	Ms	Fe	Ca
			BISHOP TUFF (from basal 4-m-thick air-fall unit analyzed by similar analytical meth-ods)																								
1	D216903	79G14	IAQ 1/, Calif.; MP; locality A; pumice lapilli	4.5	150	55	143	17.7	7.7	15.4	29.8	14	3.5	0.05	2.3	0.49	3.5	---	2.2	0.32	2.4	122	3.0	0.9	2.6	227	0.46	0.29
1	D226477	79G75	IAQ, Calif.; LP; locality B; pumice lapilli	5.4	164	38	---	19.6	7.6	16.4	39.1	17	3.9	.03	---	.70	3.6	---	2.6	.39	2.5	123	3.1	1.0	2.8	268	.47	---
1	D226478	79G77	IAQ, Calif.; MP; locality B; pumice lapilli	5.4	165	32	---	19.9	7.8	16.8	39.7	16	4.0	.04	---	.56	4.1	---	.32	2.7	.40	125	3.1	1.0	2.8	257	.46	---
1	D226479	79G78	IAQ, Calif.; UP; locality B; pumice lapilli	5.4	168	39	---	20.4	8.1	18.3	43.6	20	4.4	.04	4.8	.66	3.9	.33	2.8	.44	2.7	126	3.3	1.1	2.9	283	.54	---
1	D226482	79G81	IAQ, Calif.; LP; locality C; pumice lapilli	5.4	161	38	---	19.6	7.8	16.2	35.1	17	3.7	.05	4.4	.56	3.6	---	2.6	.39	2.5	119	3.0	1.0	2.5	257	.44	---
1	D226483	79G82	IAQ, Calif.; MP; locality C; pumice lapilli	5.4	157	40	---	19.3	7.5	17.6	35.1	17	3.8	.03	4.0	.59	4.2	---	2.5	.33	2.4	123	3.0	1.0	2.7	263	.49	---
2	D216900	79C21	Owens River, Calif.; MP; pumice lapilli	5.3	163	43	---	19.9	7.5	16.5	35.9	16	3.9	.03	4.2	.54	3.8	---	2.5	.33	2.5	122	3.2	1.0	2.8	257	.46	.30
3	D226486	79G85	Pumice quarry, northeast of Lawa, Calif.; MP	5.4	154	41	---	18.7	7.7	16.8	36.3	17	3.8	.04	---	.55	3.8	---	2.6	.35	2.3	105	2.8	1.0	2.7	245	.48	---
			Mean 2/	5.3	160	43	---	19.4	7.7	16.8	36.2	17	3.9	0.04	4.1	0.60	3.8	0.33	2.6	0.38	2.5	120	3.1	1.0	2.8	256	0.48	.30
			± One standard deviation of mean	0.3	6	10	---	0.8	0.3	0.9	4.4	2	0.3	0.01	0.9	0.07	0.3	0.01	0.2	0.04	0.1	7	0.2	0.05	0.1	14	0.03	---
1	2D	64W96	IAQ, Calif.; MP; locality D; pumice lapilli	6.5	163	54	---	19.6	7.0	18.4	35.0	15	4.4	.04	---	.34	4.2	---	1.8	.48	2.2	57	3.6	1.1	2.6	257	.51	---
1	730	64W96	IAQ, Calif.; MP; locality D; pumice lapilli	---	180	67	---	19.0	6.5	17.5	36.9	19	4.4	---	---	4.0	---	---	2.6	.52	2.5	---	4.1	---	2.9	266	.53	.30
1	NASW115	BT-4	IAQ, Calif.; 1 m below top of bed; pumice lapilli	6.0	187	---	---	21.0	6.7	19.4	47.1	20	3.7	---	---	.56	4.1	---	2.0	.37	3.2	---	3.7	---	3.1	265	.54	---
2	923K	B-93	Owens River, Calif.; pumice lapilli 3/	6.1	200	---	---	21.4	7.1	18.5	42.2	20	3.9	.04	---	.60	4.2	---	2.8	.37	3.2	---	3.9	---	2.9	281	.55	---
5	NASW3	J-328	Devils Post Pile quadrangle, Calif.; pumice lapilli 3/	6.1	185	---	---	21.9	7.2	18.3	42.1	18	3.8	.03	---	.63	4.0	---	2.9	.41	2.2	---	4.0	---	3.2	274	.50	.29
6	578	69W140	Roadcut near Toms Place, Calif.; MP; pumice lapilli	6.9	183	52	---	19.5	7.3	17.3	38.6	19	4.2	.06	---	4.2	2.5	---	2.5	.53	2.8	207	3.8	---	2.7	271	.51	.29
			BISHOP TUFF (from surge deposit overlying basal air-fall unit)																								
1	D226484	79G83	IAQ, Calif.; surge deposit; MP; locality C; pumice lapilli	5.0	153	39	---	18.7	7.1	18.7	37.9	18	3.7	0.04	---	0.55	3.8	---	2.5	0.38	2.3	98	2.9	1.0	2.6	261	0.49	---
1	D226088	80G23	IAQ, Calif.; surge deposit; MP; locality E; pumice lapilli	5.7	162	---	---	19.7	7.0	19.7	36.1	16	3.8	.04	3.5	.55	3.5	---	2.3	.34	2.3	63	3.1	0.9	2.6	241	.48	---
			BISHOP TUFF (from lowest ashflows of the lower part; nonprocessne bearing pumice)																								
1	D216904	79G15	IAQ, Calif.; thick ash-flow unit; pumice lapilli	4.6	150	---	---	19.2	8.2	22.9	45.4	17	3.9	0.04	3.6	0.52	3.0	---	2.3	0.34	2.2	124	3.1	0.9	2.5	241	0.50	0.31
1	D229087	80G21	IAQ, Calif.; lowest lenticular ash-flow; pumice lapilli	5.9	163	8	---	19.8	8.1	18.9	26.8	14	4.0	.03	---	.57	4.0	---	2.6	.37	2.5	---	4.1	---	2.9	266	.53	---
1	D226480	79G76A	IAQ, Calif.; thick ash flow unit; pumice lapilli	5.3	159	37	23	19.1	7.4	18.7	40.7	19	4.0	.05	4.2	.58	3.6	0.31	2.5	.38	2.7	137	3.2	---	3.1	265	.54	---
1	D226485	79G84	IAQ, Calif.; thick ash flow unit; pumice lapilli	5.0	144	39	96	17.8	6.6	21.5	39.3	18	3.7	.04	3.4	.50	3.6	---	2.3	.35	2.2	120	2.8	.9	2.5	250	.50	---
1	D226481	79G87	IAQ, Calif.; 4 m above 79G84; pumice lapilli	5.5	168	36	---	20.1	8.0	17.0	40.9	18	3.9	.03	4.3	.69	3.4	.33	2.7	.40	2.8	128	3.2	1.0	2.8	255	.44	---
3	D226487	79G86	Pumice quarry, northeast of Lawa, Calif.; LP, pumice lapilli	5.3	150	124	46	18.2	6.9	18.7	36.5	14	3.6	.10	3.8	.55	3.9	.24	2.1	.34	2.2	113	2.8	.9	2.9	295	.54 4/	---
			BISHOP TUFF (from lowermost ashflow of the upper part; pyroxene-bearing pumice)																								
2	D226489	79G88	Taylor Canyon, Calif.; lower part; pumice blocks	2.5	90	237	---	12.3	2.8	50.6	79.5	23	3.1	0.19	2.4	0.30	1.9	0.16	1.1	0.18	1.1	105	2.8	0.5	1.4	116	0.35	---
2	D226492	79G94	Cowtrack Mountain quadrangle, Calif.; pumice block	2.5	92	300	43	12.6	3.4	51.8	82.9	26	3.2	.22	2.7	.28	2.1	---	1.1	.18	1.1	110	3.0	.5	1.5	141	.41	---
			BISHOP ASH BEDS																								
8	7	68W156	Shoshone quadrangle, Calif. 3/	6.9	169	51	---	19.0	7.1	16.8	36.0	20	4.0	0.03	---	0.44	4.1	---	1.4	0.49	2.1	76	3.6	1.1	2.6	249	0.46	0.31
8	NASW183	Teco-5	Shoshone quadrangle, Calif. 3/	5.9	185	---	---	21.0	7.4	18.7	42.9	17	3.6	.04	---	.58	4.0	---	2.7	.36	2.1	---	3.8	---	3.0	254	.50	---
9	NASW71	Saltcn-5	Durnrid 7 1/2-minute quadrangle, Calif. 3/	5.6	185	---	---	20.2	7.5	20.2	44.2	17	3.7	.04	---	.58	3.9	---	2.5	.35	2.1	---	3.7	---	2.9	266	.49	---
9	NASW116	Saltcn-1	Durnrid 7 1/2-minute quadrangle, Calif. 3/	6.1	195	---	---	21.9	7.2	17.7	42.4	19	3.7	.03	---	.61	4.3	---	2.8	.39	2.2	---	3.8	---	3.2	272	.50	---
9	NASW53	Saltcn-2	Durnrid 7 1/2-minute quadrangle, Calif. 3/	5.3	170	---	---	18.5	5.8	25.2	51.9	20	3.5	.06	---	.52	3.3	---	2.3	.33	1.9	---	3.5	---	2.7	257	.52	---
9	NASW117	Saltcn-3a	Durnrid 7 1/2-minute quadrangle, Calif. 3/	5.6	178	---	---	20.1	6.5	21.4	48.6	18	3.8	.05	---	.58	4.0	---	2.5	.37	2.2	---	3.8	---	2.8	252	.52	---
10	576	70W4	San Joaquin Valley, Calif. 3/	5.3	155	84	---	16.8	6.1	25.2	45.8	21	4.2	.08	---	.59	4.1	---	2.1	.45	2.4	132	3.2	1.2	2.3	239	.50	---
11	NASW75	ELS1-1	Hurietta 7 1/2-minute quadrangle, Calif. 3/	5.4	181	---	---	19.8	7.4	20.3	44.6	18	3.6	.04	---	.56	3.8	---	2.4	.34	2.0	---	3.6	---	2.8	262	.50	---
14	NASW124	ST-RT-2	Idylwild 15-minute quadrangle, Calif. 3/	5.4	188	---	---	20.8	8.7	20.0	46.8	20	3.5	.04	---	.57	4.0	---	2.6	.37	2.1	---	3.6	---	3.0	266	.51	---
19	NASW4	2326188	Alpaugh 7 1/2-minute quadrangle, Calif. 3/	5.3	190	---	---	19.0	6.1	25.0	52.2	17	3.9	.04	---	.61	4.1	---	2.8	.39	2.3	---	3.7	---	3.1	265	.54	---
21	22	65W131	Centerville, Colo.; middle part of thin impure ash	6.5	158	130	---	18.1	6.2	24.8	40.6	22	3.9	.08	---	.61	3.3	---	1.6	.42	1.8	74	3.6	1.0	2.4	241	.53	.33
22	528	65W1	Paradox, Colo.; lower part	6.8	154	82	---	19.6	6.3	23.3	45.5	21	.07	---	---	.61	3.4	---	1.8	.44	2.1	91	3.7	---	2.6	247	.50	---
23	D229098	80W90	Alamosa, Colo. 3/	4.4	130	127	36	15.7	5.9	24.6	47.1	17	3.6	.08	3.2	.46	3.4	---	1.9	.29	1.9	---	2.7	.8	2.2	229	.47	.34
24	D216836	80W92	San Luis Valley, Colo.; middle part of thin impure ash	4.6	137	78	13	16.2	5.7	25.7	44.4	18	269	---	---	.60	3.4	0.33	2.0	.29	2.0	87	2.9	.9	2.4	236	.47	---
25	D216900	78W217	Red Rock Pass, Idaho 3/	4.5	148	60	---	18.1	7.3	20.9	38.5	16	3.7	.05	2.8	.51	2.9	---	2.4	.40	2.3	119	2.9	.8	2.4	248	.48	.31
25	D216899	78W218	Red Rock Pass, Idaho 3/	5.1	156	---	---	19.6	7.8	16.8	33.5	16	3.8	.04	---	.58	3.8	---	2.4	.35	2.5	124	3.1	1.0	2.5	261	.45	---
26	D198718	78W17	Gay Mines, Idaho; lower 10 cm of a 50 cm thick bed	5.7	172	45	---	20.1	8.0	17.2	38.8	18	4.0	.03	4.7	.44	4.7	.39	2.6	.37	2.6	---	3.4	1.2	2.8	252	.46	---
27	D198716	71W9	Nuckolls Co., Nebr.; from middle of thick impure bed	4.4	141	117	---	15.5	5.5	26.7	53.2	19	3.5	.04	---	.55	3.2	---	2.0	.32	1.8	---	3.0	.7	2.0	218	.51	---
27	5	64W8	Nuckolls Co., Nebr.; from middle of thick impure bed	5.3	151	102	---	15.9	5.7	27.3	50.7	25	4.4	.13	---	.57	3.0	---	2.0	.42	2.1	148	3.6	.9	2.2	230	.53	.33
27	503	64W8	Nuckolls Co., Nebr.; from middle of thick impure bed	4.8	105	105	---	16.3	5.3	27.1	51.4	21	3.6	.04	---	.73	3.5	---	2.8	.38	2.2	82	3.5	.8	2.2	242	.51	---
27	541	64W8	Nuckolls Co., Nebr.; from middle of thick impure bed	5.5	145	106	---	16.3	5.8	27.0	47.3	15	3.6	.10	---	.60	3.1	---	1.3	.39	1.7	75	3.2	.9	2.3	213	.54	---
27	D226494	64W8	Nuckolls Co., Nebr.; (coarse fraction; +120 -150 mesh); MP	4.3	132	112	---	16.2	5.8	30.3	54.3	20	4.0	.10	---	.60	3.1	---	1.9	.29	1.9	111	3.0	.8	2.2	215	.52	---
27	D226495	64W8	Nuckolls Co., Nebr.; (fine fraction; +200 -150 mesh); MP	4.4	131	86	---	16.4	5.9	27.6	47.9	19	3.5	.09	4.4	.45	3.1	.21	1.9	.29	1.6	115	2.8	.8	2.2	213	.50	---
29	983	70W11	Clayton Valley, Nev. 3/	6.5	181	63	---	17.4	6.8	21.4	44.4	21	.07	---	---	.67	3.8	---	2.1	.47	2.8	215	3.8	---	3.0	250	.49	---
30	D216894	78G203	Jackass Flats, Nev. 3/	5.0	159	38	---	18.7	8.3	16.0	32.2	16	3.6	.02	3.5	3.6	---	2.5	.37	2.4	124	3.0	1.0	2.6	253	.44	.30
31	D216893	79G61	Skeleton Hills, Nev. 3/	5.2	162	58	---	19.5	8.2	16.5	34.1	18	3.8	.03	3.8	.51	3.8	.31	2.6	.40	2.5	133	3.1	1.0	2.8	263	.47	.30
32	D216890	79G4	Striped Hills, Nev.; lower part of 1-m-thick bed	5.1	163	65	---	19.4	8.1	17.8	31.3	16	3.7	.03	3.2	.59	3.6	.30	2.5	.39	2.4	129	3.1	1.1	2.7	250	.46	.30
32	D216942	79G82	Calico Hills, Nev. 3/	5.4	157	38	---	18.3	7.2	16.7	35.1	16	3.6	.03	3.8	.60	3.6	---	2.4	.36	2.3	116	2.9	1.0	2.7	234	.45	.29
33	D229069	80W71	Big Dune quadrangle, Nev. 3/	5.7	163	36	---	19.3	7.8	15.7	33.8	17	3.9	.04	4.1	.60	3.6	.38	2.4	.36	2.5	---	3.1	.9	2.7	256	.48	.36
33	D229070	80W70	Big Dune quadrangle, Nev. 3/	5.6	160	32	---	19.3	7.4	18.4	38.4	17	4.0	.04	4.0	.60	3.8	---	2.4	.38	2.4	---	3.3	1.0	2.8	253	.49	.32
34	D198713	73W101	Grama, N. Mex.; all samples from middle of 30-cm-thick bed	5.4	157	74	---	16.9	6.3	27.1	56.3	19	3.4	.09	3.4	.52	2.9	.32	2.0	.29	2.1	---	3.2	.7	2.1	216	.47	---
34	D226497	73W101	Grama, N. Mex.; (coarse fraction; +120 -100 mesh)	4.0	128	93	16	15.1	5.5	29.4	50.1	16	3.4	.09	---	.43	3.1	.20	1.7	.26	1.7	109	2.7	.7	2.1	219	.49	---
34	D226498	73W101	Grama, N. Mex.; (fine fraction; +200 -150 mesh)	4.5	161	70	---	16.1	5.9	27.2	52.8	18	3.5	.09	---	.52	3.2	.23	1.9	.29	2.0	128	2.8	.8	2.2	219	.51	---
35	D198712	70W156	Franklin Mountains, N. Mex.; from middle of 5-cm-thick bed	3.9	127	110	33	14.7	8.6	25.1	50.2	19	3.2	.08	3.1	.44	3.1	.33	1.7	.21	1.8	---	2.8	.9	2.0	189	.45	.31
35	723	70W156	Franklin Mountains, N. Mex.; from middle of 5-cm-thick bed	3.0	148	142	---	15.4	7.0	26.4	49.0	22	3.6	---	---	.50	3.1	---	2.1	.39	2.1	---	3.4	---	2.1	202	.51	---
36	D198708	75K61	Mineral Mountains, Utah; upper part of 2-m-thick bed	4.9	159	71	---	18.1	8.0	23.4	49.0	19	3.4	.06	3.9	.52	3.9	.40	2.2	.32	2.4	---	3.2	1.0	2.5	253	.50	.38
36	D216833	80G15	Mineral Mountains, Utah; basal 5-10 cm of 2-m-thick bed	5.9	162	---	---	19.8	8.2	17.6	34.1	18	3.8	.03	---	.58	3.8	.41	2.7	.42	2.6	---	3.4	1.1	2.8	263	.47	---
38	19	65W5	Polar Mesa quadrangle, Utah; lowest 6 cm of 1-m-thick bed	5.4	153	68	---	17.9	6.9	18.0	31.3	18	3.9	.03	---	.37	3.7	---	1.5	.45	2.0	88	3.3	1.0	2.4	244	.44	.30
38	NASW149	65W5	Polar Mesa quadrangle, Utah; lowest 6 cm of 1-m-thick bed	6.2	202	---	---	21.9	7.2	19.1	43.4	17	3.8	.04	---	.62	4.2	---	2.3	.37	3.1	---	4.2	---	3.2	279	.51	---
39	D216895	79G39	Delta, Utah; lower part of 25-cm-thick ash bed	4.9	156	---	---	18.4	7.9	15.5	31.4	15	3.5	.03	---	.44	3.5	.27	2.4	.37	2.3	---	2.9	1.0	2.6	244	.44	.31
40	D216901	79G85	Sevier Lake, Utah 3/	3.9	161	---	---	16.6	5.6	22.8	51.4	20	3.4	.08	---	.48	2.6	---	2.0	.29	1.7	---	3.1	.7	2.0	273	.49	.30
40	D229085	80W84	Sevier Lake, Utah 3/	4.2	132	---	---	15.6	6.4	22.0	44.8	19	4.1	.05	2.7	.48	3.5	---	1.8	.26	2.0	107	2.9	1.0	2.5	266	.47	---
40	D234856	80W84	Sevier Lake, Utah 3/	4.0	130	---	---	15.5	5.7	21.6	42.8	19	4.0	.04	3.0	.47	2.9	---	1.8	.26	1.9	---	2.8	.7	2.0	246	.47	---
41	D198709	75W58	Cove Fort, Utah; MP	5.5	170	---	128	19.5	8.6	19.3	35.1	15	3.4	.02	---	.60	4.6	.52	2.9	.37	2.5	---	3.2	1.1	2.7	276	.45	---
42	D225437	79W101	Black Rock, Utah; 3/	6.5	161	39	18	18.5	7.2	17.4	33.1	15	3.9	.03	---	.52	3.6	---	2.5	.36	2.3	118	2.9	1.0	2.6	260	.47	---
43	28	57P133	Saltair, Utah	6.0	147	49	---	17.0	6.5	22.4	38.9	21	4.0	---	---	.60	3.5	---	1.5	.40	1.9	81	3.3	.9	2.3	244	.52	.36
44	29	70W6	Wendover, Utah 3/	6.5	162	51	---	17.4	6.8	17.7	33.0	16	4.0	.06	---	.59	3.6	---	1.4	.45	2.1	91	3.6	1.1	2.8	238	.48	.31
45	27	67W161	Payson, Utah; lower 15 cm of 2.5-m-thick bed	6.5	161	105	---	18.5	6.3	21.4	40.7	20	3.9	.04	---	.61	3.2	---	1.5	.45	2.1	95	3.7	1.1	2.5	244	.52	.31
45	802A	67W161	Payson, Utah; lower 15 cm of 2.5-m-thick bed	5.3	149	58	---	18.2	6.0	19.8	38.4	16	3.8	.03	---	.57	3.2	---	1.5	.42	2.2	107	2.8	1.0	2.5	266	.47	---
46	D229086	80G18	Payson, Utah; lower 10 cm of 1-m-thick bed	5.8	159	---	---	19.4	7.6	15.8	32.9	16	3.8	.02	3.9	.58	3.7	.30	2.5	.35	2.4	112	3.1	1.0	2.7	258	.46	---
46	D198710	74W24	Laramie, Wyo.; lowest 6 cm of 25-cm-thick bed	5.2	156	32	---	19.8	7.2	19.6	44.1	19	3.5	.04	3.4	.57	4.1	.39	2.3	.33	2.4	---	3.2	1.2	2.5	230	.47	.30

1/ IAQ, Insulating Aggregates pumice quarry north of Bishop, Calif., now abandoned
2/ Mean of only those samples analyzed by H. T. Millard, D. M. McKown, and R. J. Knight at the U.S. Geological Survey laboratory in Denver, Colo.
3/ Not known by me where sample was collected stratigraphically within the ash bed
4/ Here questionably included with the Bishop Tuff; the iron and manganese contents are anomalously high compared to other Bishop Tuff samples
5/ From 2-m-thick bed in the Borrego Formation in the Salton Trough; this sample referred to as the Insulating Aggregate Quarry type of Bishop ash by Sarna-Wojcicki and others (1980)
6/ From 2-m-thick bed in the Borrego Formation in the Salton Trough; this sample referred to as the Owens River Gorge type of Bishop ash by Sarna-Wojcicki and others (1980)
7/ From 2-m-thick bed in the Borrego Formation in the Salton Trough; this sample referred to as the Priest Pumice mine type of Bishop ash by Sarna-Wojcicki and others (1980)

Table 3.--Chemical analyses of the glass phases of some Pliocene and Pleistocene rhyolite tephra units compositionally and mineralogically similar to the Bishop Tuff and ash beds in the Long Valley-Glass Mountain area, Calif., and some ash beds in California, Nevada, and Utah suspected to be their correlatives

[Locality descriptions given in table 4; analyses for all elements done by the instrumental neutron activation method except for Ca which was made by atomic absorption methods; analysts for samples beginning with the letter D was H. T. Millard, D. M. McKown, and R. J. Knight; analyst for samples with laboratory numbers composed only of numerals was G. A. Borchardt; other chemical analyses reported by Sarna-Wojcicki and others (1980); leaders (---) indicate no data; samples with identical field numbers but different laboratory numbers were analyzed during different analytical runs; some ash bed names are those used by Izett (1981) except for newly named ash beds of this report; amounts of elements in parts per million except Fe and Ca which are listed in weight percent]

Lab. No.	Sample No.	Locality and sampled material	Ca	Rb	Ba	Sr	Th	U	La	Ce	Nd	Sm	Eu	Gd	Tb	Dy	Tm	Yb	Lu	Ta	Zr	Hf	Sb	Sc	Ms	Fe	Ca
		FRIANT MINE CONGLOMERATE UNIT																									
D226475	79G73A	Friant, Calif.; pumice cobbles	4.6	147	88	---	17.8	6.7	24.3	50.5	21	3.6	0.07	3.9	0.56	3.2	0.28	2.3	0.34	2.2	119	3.0	0.9	2.5	224	0.47	---
NASW2	63s326	Friant, Calif.; pumice cobbles	5.4	171	---	---	19.4	6.1	24.1	50.8	20	3.6	.04	---	.53	3.4	---	2.4	.30	1.9	---	3.6	---	2.8	252	.52	---
		MILLERTON LAKE ASH BED (AGE UNCERTAIN)																									
D226476	79G74	Friant, Calif.; 3-m-thick ash bed	4.7	151	50	---	17.9	6.8	21.7	46.5	18	3.6	0.05	4.3	0.58	3.4	0.28	2.4	0.34	2.2	120	3.0	0.9	2.5	231	.40	---
D198717	70W1	Friant, Calif.; 3-m-thick ash bed	5.0	159	73	---	18.3	6.8	23.6	51.5	18	3.7	.06	---	.55	3.5	---	2.3	.28	2.3	131	3.2	1.0	2.5	223	.38	0.29
		CLASS MOUNTAIN-D ASH BED (ABOUT 1.0 M.Y.)																									
D226905	79G12	Glass Mountain quadrangle, Calif.; pumice blocks	5.0	166	86	95	18.8	7.6	17.7	35.0	19	4.0	0.05	---	0.56	3.8	---	2.6	0.37	2.5	111	3.0	0.9	2.9	274	.53	.35
D226488	79G87	White Mountain Peak quadrangle, Calif.; pumice lapilli	5.3	159	81	---	19.8	7.6	19.3	39.8	19	4.1	.05	3.4	.56	3.6	---	2.6	.40	2.4	111	3.1	1.0	3.0	287	.61	---
D198714	75W42	Bishop quadrangle, Calif.; volcanic ash below Bishop Tuff	4.8	154	56	---	17.2